LOWER ARKANSAS RIVER BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody: Arkansas River, Hutchinson to Wichita
Water Quality Impairment: Total Phosphorus

1. INTRODUCTION

Subbasin: Gar-Peace

Counties: Rice, Reno, Harvey, Sedgwick

HUC8: 11030009 **HUC10** (12): **04** (07)

HUC8: 11030010 **HUC10** (12): **01** (01, 08)
02 (01, 02, 03, 04, 05, 06, 07, 08)

Ecoregion: Level III: Central Great Plains
Level IV: Great Bend Sand Prairie (27c) and Wellington-McPherson Lowland (27d)

Drainage Area: Approximately 390 mi^2

Main Stem Water Quality Limited Segments and Tributaries (*designated uses for main stem and tributary segments are detailed in* ***Table 1)*****:**

Main Stem	***Tributaries***
HUC8 11030010	
Arkansas River (5)	
Arkansas River (4)	
Arkansas River (3)	
Arkansas River (1)	Gar Creek (8)
	Big Slough (9011)

Table 1. Designated uses for main stem and tributary segments in the watershed, Kansas Surface Water Register, December 12, 2013.

Stream	Segment #	Expected Aquatic Life	Contact Recreation	Domestic Supply	Food Procurement	Ground Water Recharge	Industrial Water Use	Irrigation Use	Livestock Watering Use
HUC 8: 11030010									
Arkansas River	***5***	***E***	***B***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***
Arkansas River	***4***	***E***	***B***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***
Arkansas River	***3***	***E***	***B***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***
Arkansas River	***1***	***S***	***B***	***Y***	***Y***	***Y***	***Y***	***Y***	***Y***
Gar Creek	8	E	a	N	Y	Y	N	Y	Y
Big Slough	9011	E	b	N	Y	Y	N	Y	Y

Y = use is designated; N = use is not designated; E=Expected aquatic life; S=Special Aquatic Life
Contact Recreation: A, B, C=Primary Contact Recreation; a, b=Secondary Contact Recreation

303(d) Listings: Station SC523 **(Figure 1)**, Arkansas River near Hutchinson.
Biology TMDL (Cat. 4a): 2008, 2010, 2012, 2014, 2016 and 2018.
Unimpaired for Total Phosphorus (Cat. 1).
Lower Arkansas River Basin Streams.

Station SC524 **(Figure 2)**, Arkansas River near Yoder.
Biology TMDL (Cat. 4a): 2002, 2004, 2008, 2010, 2012, 2014, 2016 and 2018.
Total Phosphorus (TP) Impairment (Cat. 5): 2008, 2010, 2012, 2014, 2016 and 2018.
Lower Arkansas River Basin Streams.

Station SC536 **(Figure 3)**, Arkansas River near Maize.
Biology TMDL (Cat. 4a): 2008, 2010, 2012, 2014, 2016 and 2018.
Total Phosphorus (TP) Impairment (Cat. 5): 2008, & 2010.
Total Phosphorus (TP) Impairment (Cat. 2): 2012, 2014, 2016 and 2018.
Lower Arkansas River Basin Streams.

Station SC758 (**Figure 4**), Arkansas River at Wichita.
Unimpaired for Total Phosphorus (Cat. 1).
Lower Arkansas River Basin Streams.

Figure 1. Map of contributing area for KDHE stream chemistry station SC523, Arkansas River near Hutchinson.

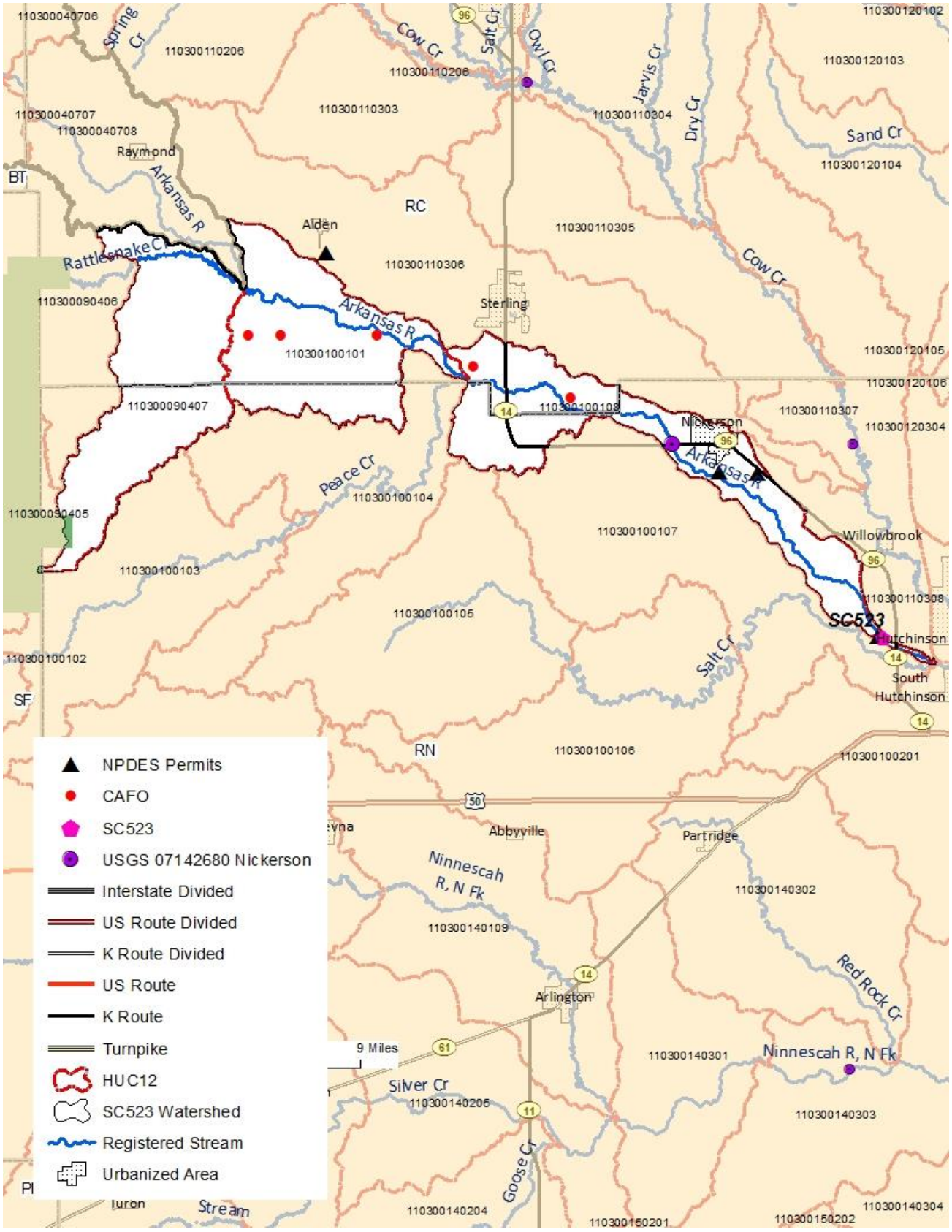


Figure 2. Map of contributing area for KDHE stream chemistry station SC524, Arkansas River near Yoder.

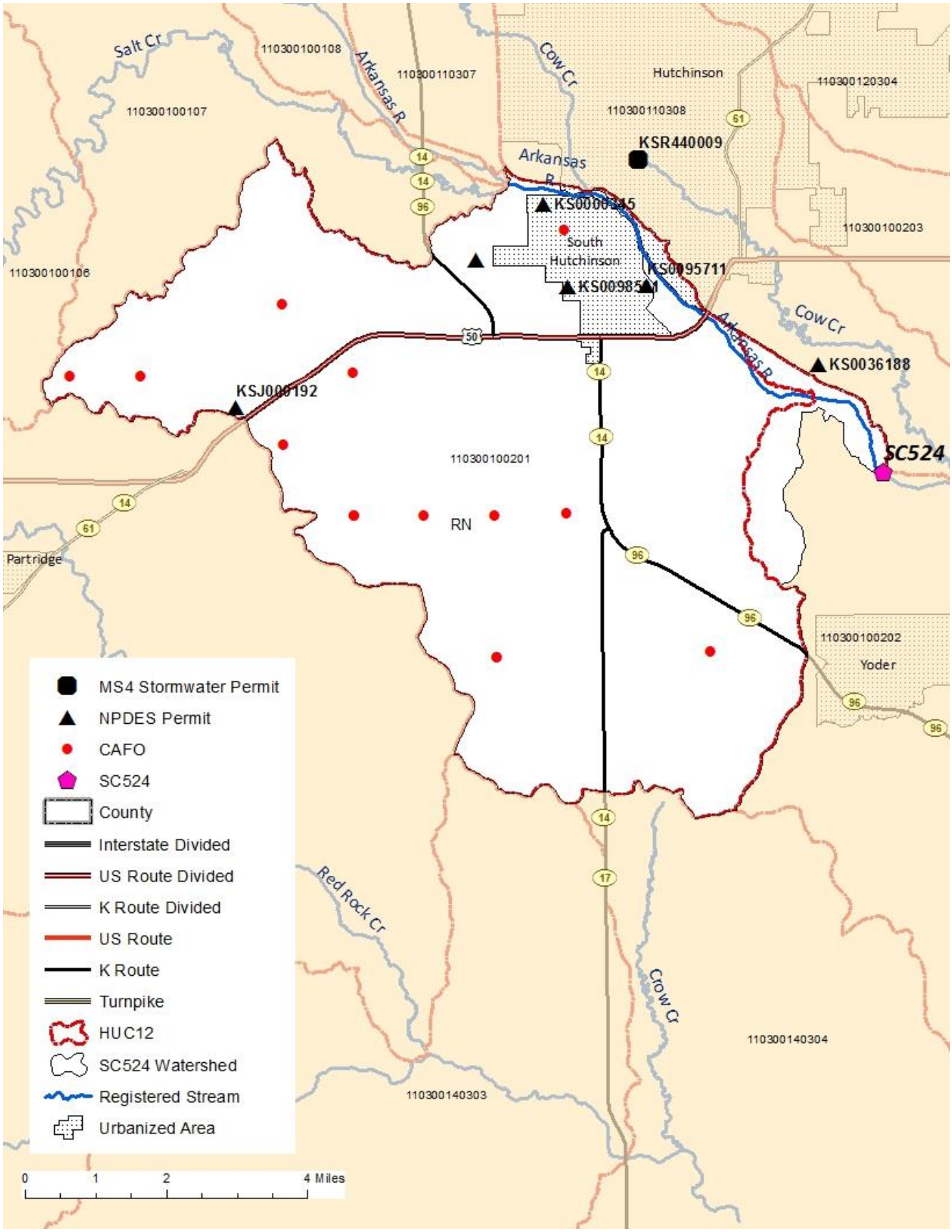


Figure 3. Map of contributing area for KDHE stream chemistry station SC536, Arkansas River near Maize.

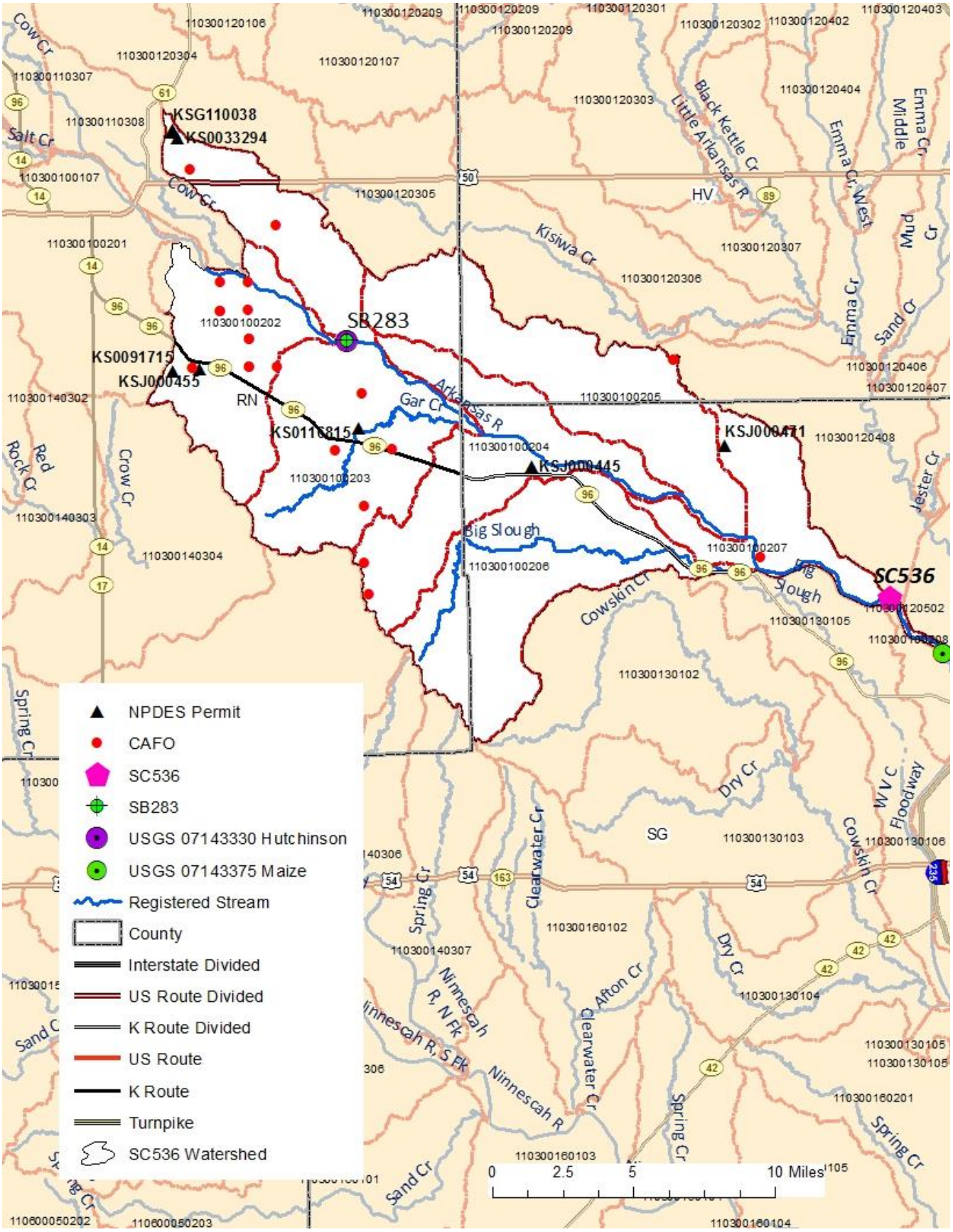
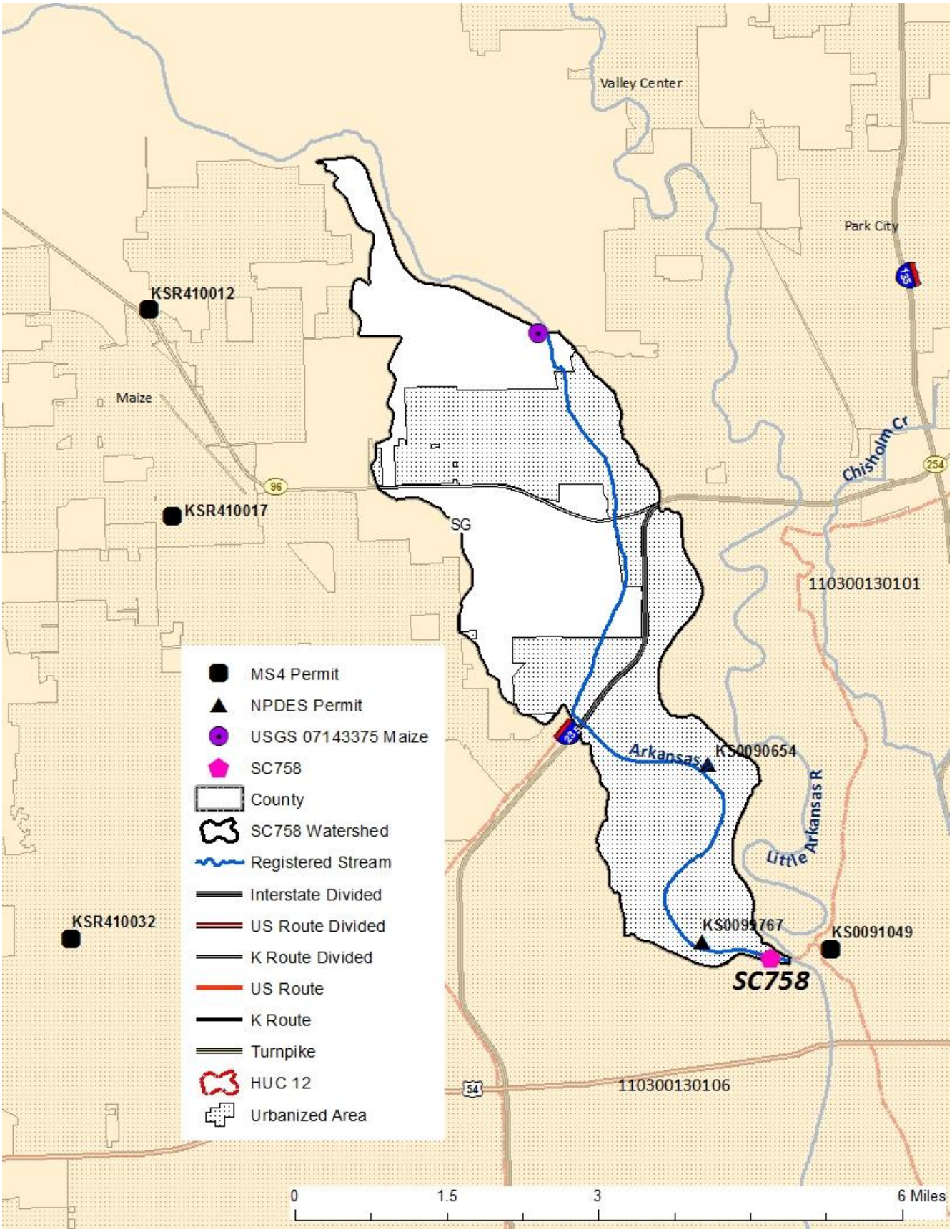


Figure 4. Map of contributing area for KDHE stream chemistry station SC758, Arkansas River at Wichita.



Impaired Use: Aquatic Life, Contact Recreation, and Domestic Water Supply.

Water Quality Criteria:
Nutrients – Narratives: The introduction of plant nutrients into streams, lakes, or wetlands from artificial sources shall be controlled to prevent the accelerated succession or replacement of aquatic biota or the projection of undesirable quantities or kinds of aquatic life (K.A.R. 28-16-28e(d)(2)(A)).

The introduction of plant nutrients into surface waters designated for domestic water supply use shall be controlled to prevent interference with the production of drinking water (K.A.R. 28-16-28e(d)(3)(D)).

The introduction of plant nutrients into surface waters designated for primary or secondary contact recreational use shall be controlled to prevent the development of objectionable concentrations of algae or algal by-products or nuisance growths of submersed, floating, or emergent aquatic vegetation (K.A.R. 28-26-28e(d)(7)(A)).

Taste-producing and odor-producing substances of artificial origin shall not occur in surface waters at concentrations that interfere with the production of potable water by conventional water treatment processes, that impart an unpalatable flavor to edible aquatic or semiaquatic life or terrestrial wildlife, or that result in noticeable odors in the vicinity of surface waters (K.A.R. 28-16-29e(b)(7)).

Dissolved Oxygen – Numeric: The concentration of dissolved oxygen in surface waters shall not be lowered by the influence of artificial sources of pollution. The Dissolved Oxygen criterion is 5.0 mg/L (K.A.R. 28-16-28e Tables of Numeric Criteria).

pH – Numeric: Artificial sources of pollution shall not cause the pH of any surface water outside of a zone of initial dilution to be below 6.5 and above 8.5 (K.A.R. 28-16-28e Tables of Numeric Criteria

2. CURRENT WATER QUALITY CONDITIONS AND DESIRED ENDPOINT

Level of Support for Designated Uses, 2016 (303)d List:
Phosphorus levels in the Arkansas River watersheds from Yoder (SC524) to Wichita (SC758) are consistently high. Excessive nutrients are not being controlled and are thus impairing aquatic life, domestic water supply, and contact recreation. The ultimate endpoint of the Total Maximum Daily Load (TMDL) will be to achieve the Kansas Surface Water Quality Standards by eliminating excessive primary productivity and impairment to aquatic life, domestic water supply, and recreation associated with excessive phosphorus. Additionally, the TMDL will serve to protect segments 110300104 and 110300105, as measured at Hutchinson (SC523), from future degradation.

Station Location and Period of Record:
Stream Chemistry (SC) Monitoring Station:
SC523: Active, permanent station at Arkansas River near Hutchinson, located on County Road Bridge 1.5 miles west of Hutchinson. Period of record: March 19, 1990 to April 17, 2017.
SC524: Active, permanent station at Arkansas River near Yoder, located on County Road Bridge 3 miles north of Yoder on Yoder Road. Period of record: March 19, 1990 to April 17, 2017.
SC536: Active, permanent station at Arkansas River near Maize, located on County Road Bridge 2 miles north of Maize. Period of record: March 21, 1990 to April 18, 2017.

SC758: Active, permanent station at Arkansas River at Wichita, located on North Seneca Street Bridge in Wichita. Period of record: March 3, 2010 to April 18, 2017.

Stream Biology (SB) Monitoring Station:

SB283: Active station at Arkansas River near Haven, located 3.0 miles north of Haven. Period of record: October 3, 1990 to October 13, 2016.

Streamflow Gage:

U.S. Geological Survey 07141300: Arkansas River at Great Bend. Period of record: January 1, 1990 to June 30, 2017.

U.S. Geological Survey 07142680: Arkansas River at Nickerson. Period of record: July 1, 1997 to April 7, 2014 and May 20, 2014 to June 30, 2017. Located near Hutchinson (SC523).

U.S. Geological Survey 07143330: Arkansas River at Hutchinson. Period of record: January 1, 1990 to June 30, 2017. Located near Yoder (SC524).

U.S. Geological Survey 07143375: Arkansas River at Maize. Period of record: January 1, 1990 to June 30, 2017. Located near Maize (SC536) and Wichita (SC758).

Hydrology: Flow conditions for this TMDL were analyzed using U.S. Geological Survey (USGS) streamgage data from the Arkansas River at Great Bend (07141300), Nickerson (07142680), Hutchinson (07143330), and Maize (07143375). All gages except Nickerson have streamflow data available for the period of record January 1, 1990 to June 30, 2017. The gage at Nickerson has streamflow data available for the period of record July 1, 1997 to April 7, 2014 and May 20, 2014 to June 30, 2017; flow values for the missing period of record were estimated with a regression analysis based upon the upstream streamflow record at Great Bend and assigned to samples collected during the unavailable periods of record.

Flow duration curves for Nickerson, Hutchinson, and Maize indicate increasing flow from the upstream (Nickerson) to downstream (Maize) sites during above normal (0-25%) and normal (26-75%) flows (**Figure 5**). During low (76-100%) flows, however, streamflow near Maize declines below levels typically seen at the upstream sites; this is likely due to groundwater recharge of the underlying Equus Beds Aquifer in the Arkansas River watershed.

Flow conditions for Kansas Department of Health and Environment (KDHE) stream chemistry (SC) stations were calculated using USGS streamgages and a watershed area ratio (**Table 2**). The KDHE SC station ratios were based upon the following USGS streamgages: Arkansas River near Hutchinson (SC523) utilized streamflow from Nickerson (07142680), Arkansas River near Yoder (SC524) utilized streamflow from Hutchinson (07143330), Arkansas River near Maize (SC536) utilized streamflow from Maize (07143375), and Arkansas River at Wichita (SC758) utilized streamflow from Maize (07143375). Long term estimated flows for the Arkansas River and its tributaries can be found in **Table 3** (Perry et. al, 2004). The main tributaries to the Arkansas River are: Peace Creek, which enters the Arkansas River above Hutchinson (SC523); Salt Creek and Cow Creek (110300111), which enter the Arkansas River above Yoder (SC524); and Gar Creek and Big Slough, which enter the Arkansas River above Maize (SC536).

Figure 5. Flow duration curve for U.S. Geological Survey gaged sites located in the Arkansas River, January 1, 1990 (Nickerson begins July 1, 1997) to June 30, 2017.

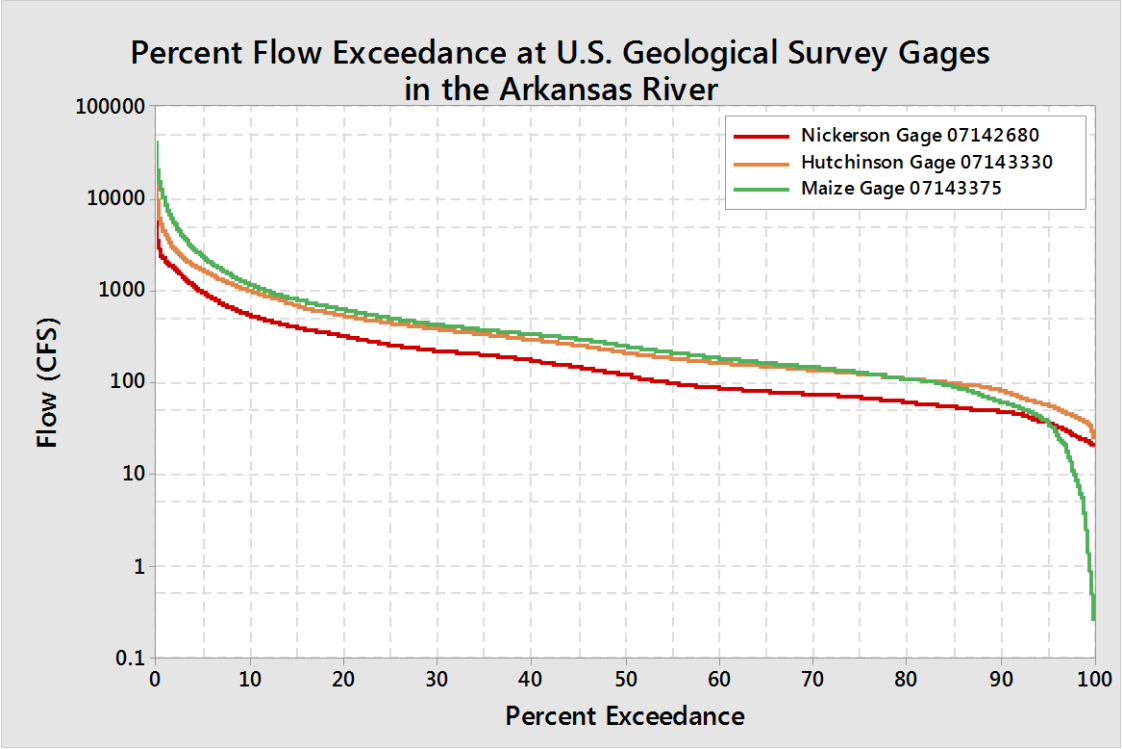


Table 2. Flow conditions and drainage area at U.S. Geological Survey gages and Kansas Department of Health and Environment stream chemistry (SC) stations in the Arkansas River, January 1, 1990 to June 30, 2017. Description: * - data based upon January 1, 1997 to June 30, 2017 period of record.

Stream	Station	Contributing Drainage Area (mi^2)	Mean Flow (CFS)	Percent of Flow Exceedance (CFS)				
				90%	75%	50%	25%	10%
Arkansas R at Nickerson	07142680*	29,444	254	46	67	117	251	530
Arkansas R near Hutchinson	SC523*	29,456	253	46	67	117	251	530
Arkansas R near Yoder	SC524	29,513	426	76	113	193	408	904
Arkansas R at Hutchinson	07143330	31,724	458	82	121	207	439	972
Arkansas R near Maize	SC536	31,910	665	61	124	245	498	1,149
Arkansas R at Maize	07143375	31,924	665	61	124	245	498	1,150
Arkansas R at Wichita	SC758	31,937	666	61	124	245	498	1,150

Table 3. U.S. Geological Survey (USGS) long term estimated flows for the Arkansas River and its tributaries (Perry et.al, 2004).

Stream	USGS Site	KSWR CUSEGA Number	County	Drainage Area (mi^2)	Mean Flow (CFS)	Flow Exceedance (%)					2-year Peak (CFS)
						90%	75%	50%	25%	10%	
Arkansas R	**3280**	**110300041**	**RC**	**33,614**	**328**	**42**	**69**	**140**	**303**	**681**	**3,550**
Peace Cr	3415	110300106	RN	174	19	3	5	7	11	22	900
Arkansas R	**3567**	**110300104**	**RN**	**35,200**	**453**	**73**	**118**	**219**	**426**	**941**	**4,020**
Salt Cr	3571	110300107	RN	130	20	2	3	5	11	24	1,230
Cow Cr	3578	110300111	RN	886	110	7	12	24	53	185	2,210
Arkansas R	**3681**	**110300101**	**RN**	**36,228**	**536**	**94**	**151**	**272**	**507**	**1,115**	**4,330**
Cow Cr	3680	110300111755	RN	30	6	1	1	2	2	5	500
Gar Cr	3883	110300108	RN	52	15	0	1	3	7	19	1,310
Big Slough	3955	110300109011	SG	59	18	0.2	2	4	10	23	1,410
Arkansas R	**3954**	**110300101**	**SG**	**36,403**	**646**	**78**	**142**	**291**	**561**	**1,200**	**6,540**
Arkansas R	**4164**	**110300101**	**SG**	**36,500**	**730**	**64**	**134**	**303**	**600**	**1,260**	**8,270**

Description: RC - Rice; RN - Reno; SG - Sedgwick.

Annual mean flows at all gages are higher than median flows, with the high annual mean and median flows occurring in 1999 at Nickerson (**Figure 6**) and in 1993 at Hutchinson and Maize (**Figures 7-8**). The lowest annual mean flows occurred in 2012 at Nickerson and Hutchinson and in 1991 at Maize. The lowest annual median flows occurred in 2012 at Nickerson, Hutchinson, and Maize. Annual flows generally coincide with National Oceanic and Atmospheric Administration (NOAA) annual total precipitation from Hutchinson station USC00143930, especially during years of extremely low flow and precipitation. Annual peak flows occurred in 2007 at Nickerson and Hutchinson (**Figures 9-10**) and in 1993 at Maize (**Figure 11**).

Figure 6. Annual mean and median flows for U.S. Geological Survey gage 07142680 at Nickerson located near Hutchinson (SC523) in the Arkansas River, July 1, 1997 to June 30, 2017, and annual total precipitation at NOAA station USC00143930 in Hutchinson, January 1990 to December 2016.

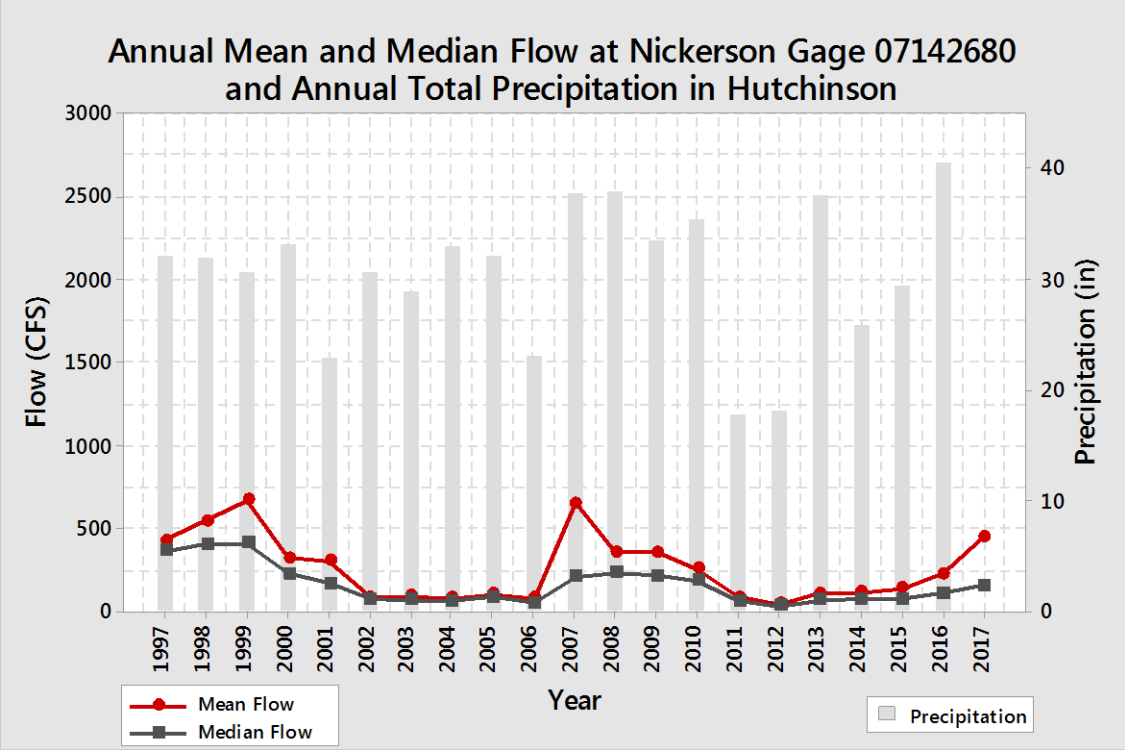


Figure 7. Annual mean and median flows for U.S. Geological Survey gage 07143330 at Hutchinson located near Yoder (SC524) in the Arkansas River, January 1, 1990 to June 30, 2017, and annual total precipitation at NOAA station USC00143930 in Hutchinson, January 1990 to December 2016.

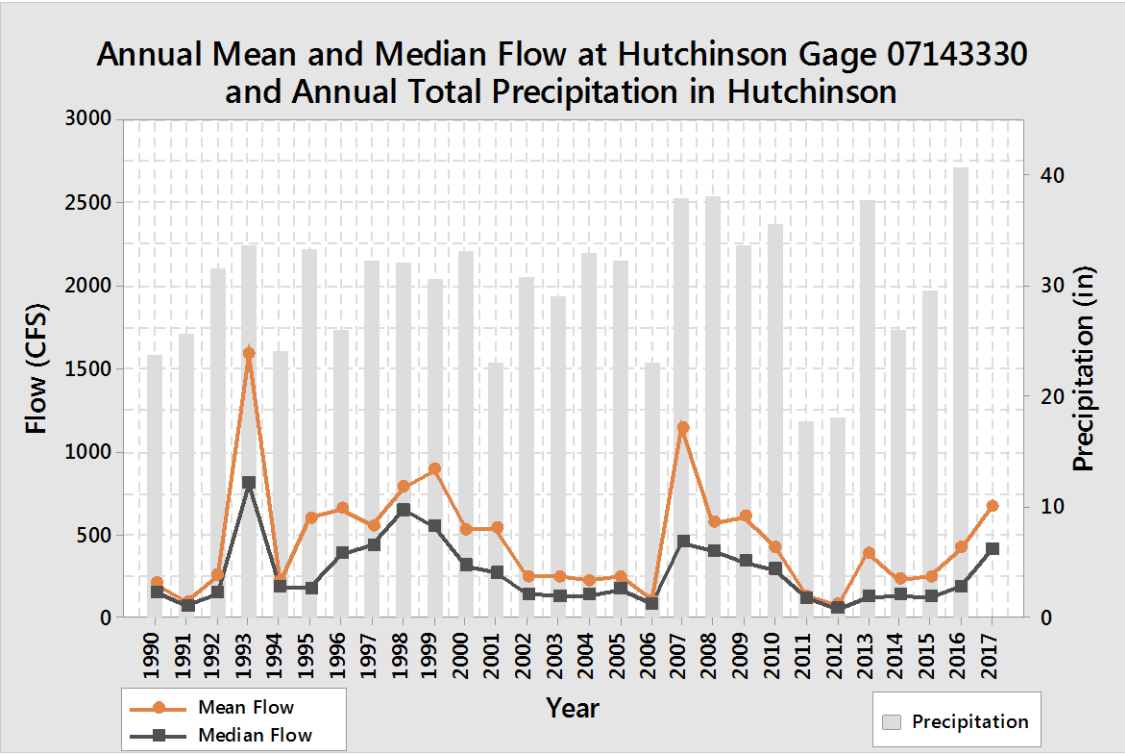


Figure 8. Annual mean and median flows for U.S. Geological Survey gage 07143375 near Maize located near Maize (SC536) and Wichita (SC758) in the Arkansas River, January 1, 1990 to June 30, 2017, and annual total precipitation at NOAA station USC00143930 in Hutchinson, January 1990 to December 2016.

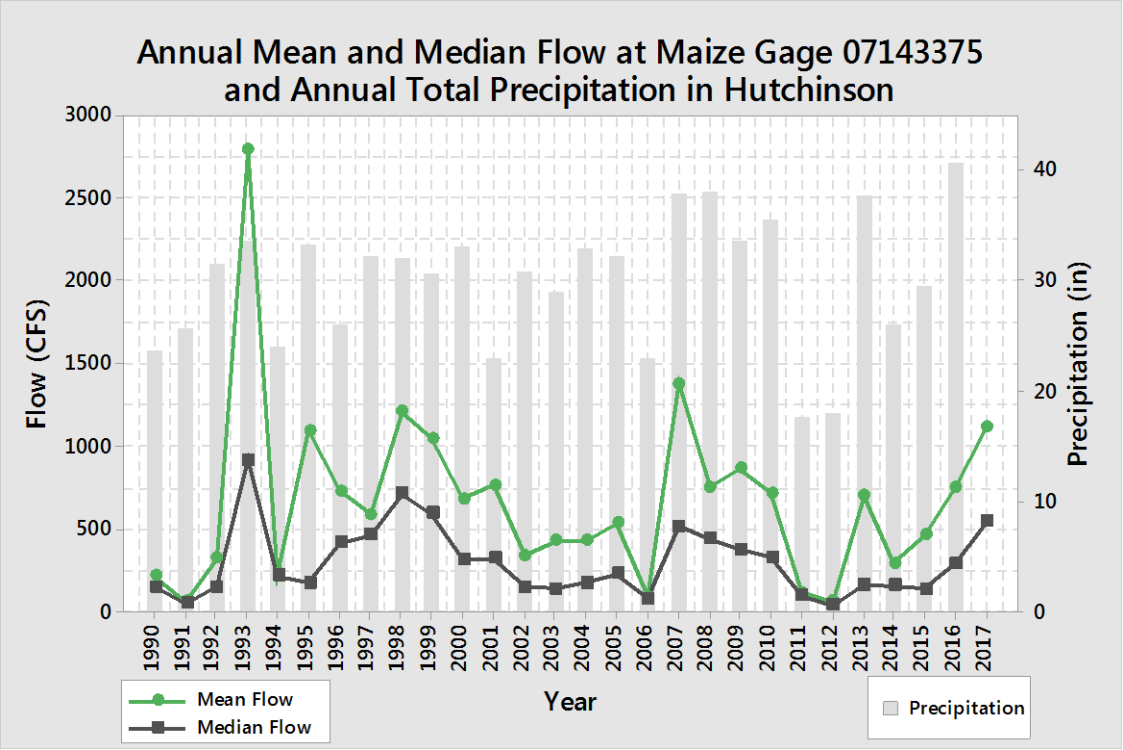


Figure 9. Annual peak flows for U.S. Geological Survey gage 07142680 at Nickerson located near Hutchinson (SC523) in the Arkansas River, July 1, 1997 to June 30, 2017.

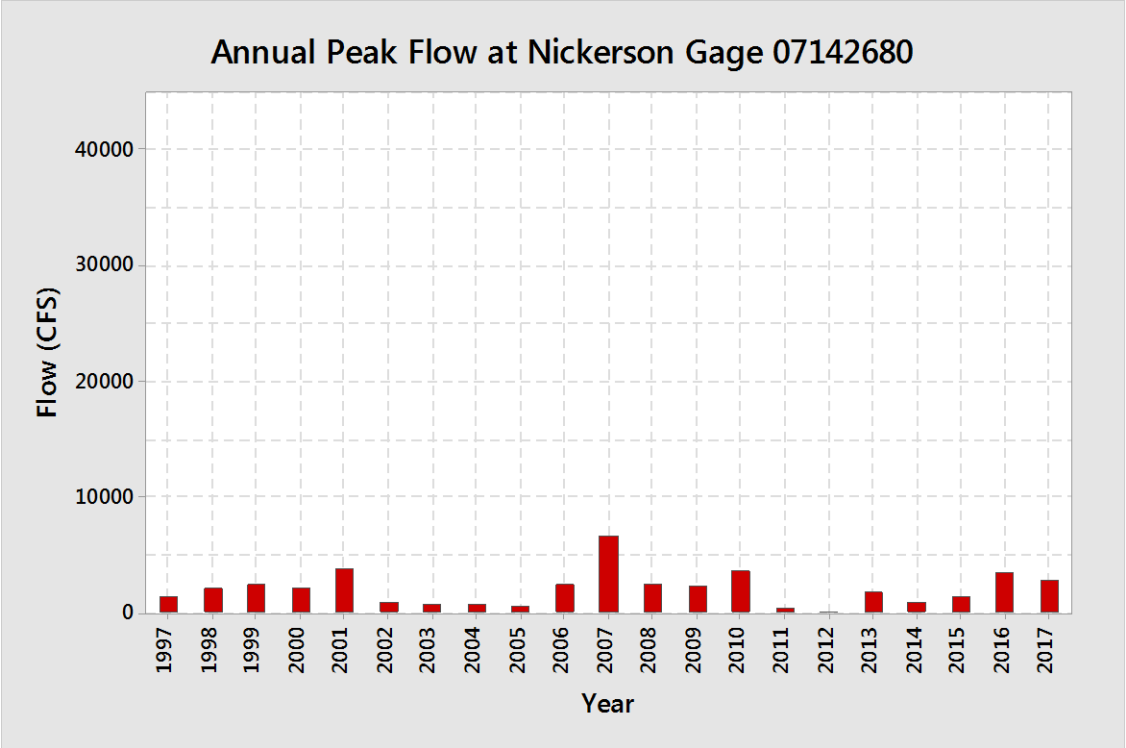


Figure 10. Annual peak flows for U.S. Geological Survey gage 07143330 at Hutchinson located near Yoder (SC524) in the Arkansas River, January 1, 1990 to June 30, 2017.

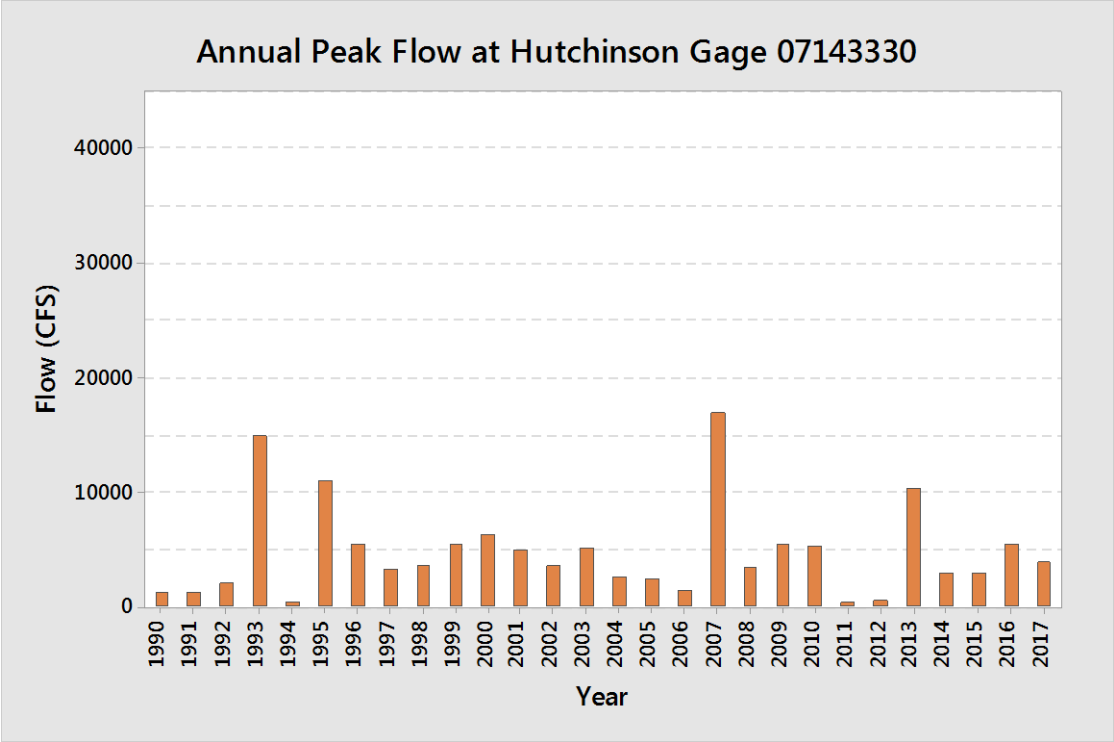
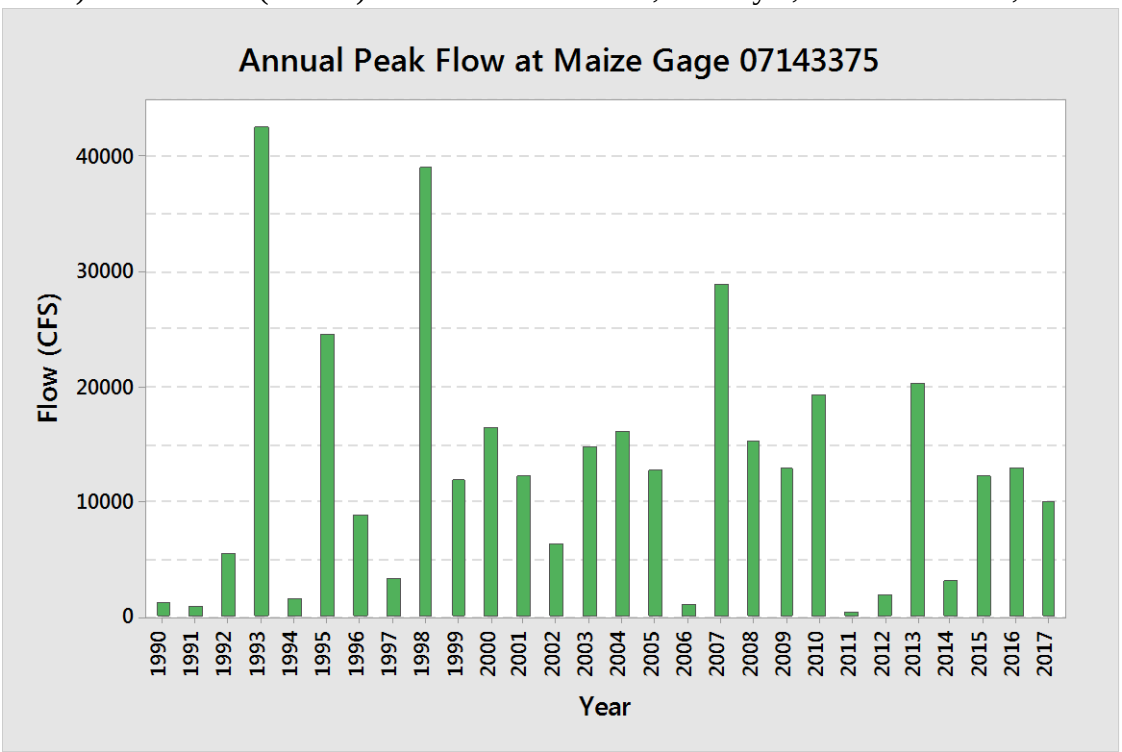
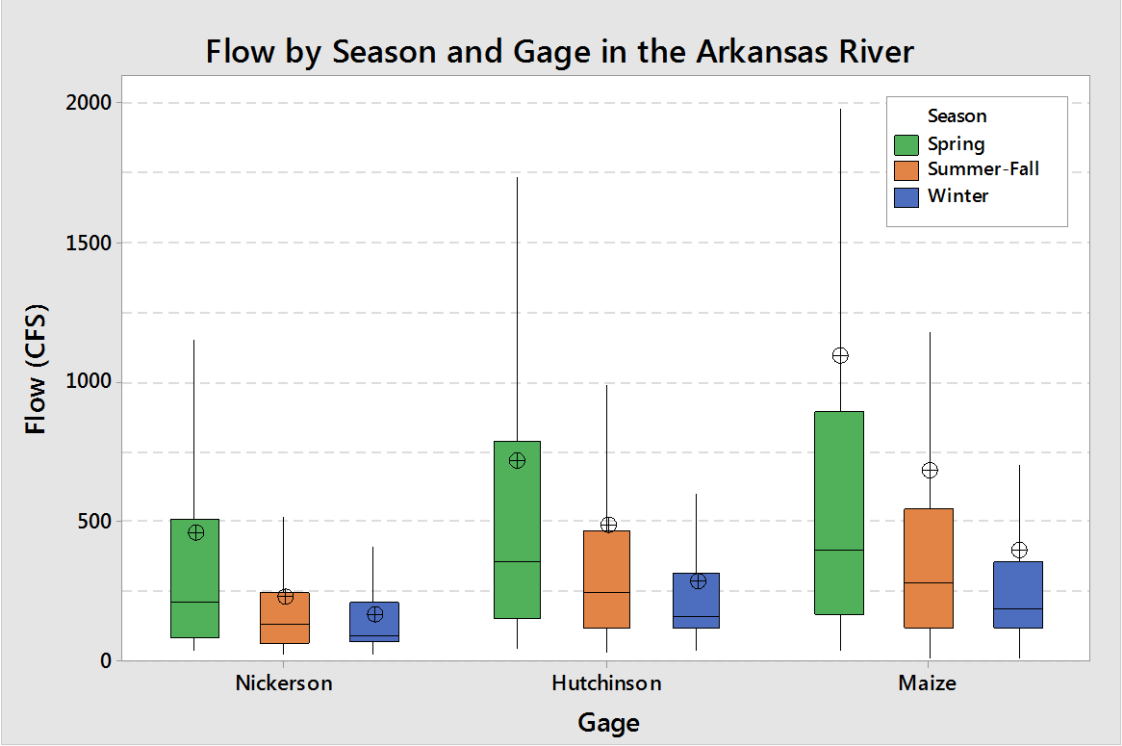


Figure 11. Annual peak flows for U.S. Geological Survey gage 07143375 near Maize located near Maize (SC536) and Wichita (SC758) in the Arkansas River, January 1, 1990 to June 30, 2017.



Seasonally, high flows occur in spring (April through June) and low flows occur in winter (November through March; **Figure 12**). Accordingly, monthly mean and median flows at all gages are typically highest in May and June and lowest in November, December, and January. Across all seasons, flow is highest at Maize, the most downstream location.

Figure 12. Flows by season for U.S. Geological Survey gaged sites located in the Arkansas River, January 1, 1990 (Nickerson begins July 1, 1997) to June 30, 2017.



Total Phosphorus: As the boxplots in **Figure 13** display, mean and median total phosphorus (TP) concentrations are highest near Yoder (SC524) and Maize (SC536) over the 1990-2017 period of record with median TP concentrations of 0.340 and 0.270 mg/L, respectively. Near Hutchinson (SC523), the uppermost station in the watershed, the median TP concentration is 0.148 mg/L over the period of record. At Wichita (SC758), the lowest station in the TMDL watershed, median TP is 0.130 mg/L. It should be noted that Wichita (SC758) is comparatively new, with its period of record beginning in 2010, and has a considerably smaller data set than the other three SC stations (**Table 4)**.

Figure 13. Total phosphorus by station in the Arkansas River, March 19, 1990 to April 18, 2017.

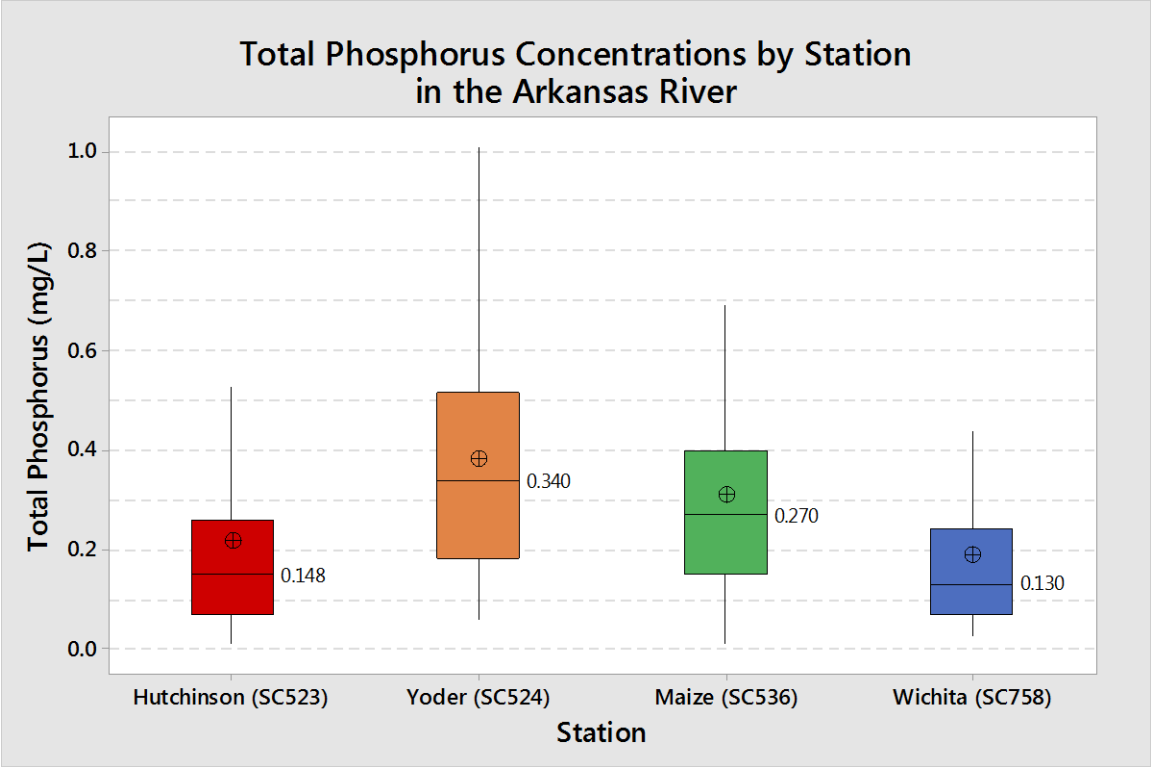


Table 4. Total phosphorus mean, median, and sample number (N) in the Arkansas River, March 19, 1990 to April 18, 2017.

Station	Stream	Mean	Median	N
SC523	Arkansas River near Hutchinson	0.215	0.148	145
SC524	Arkansas River near Yoder	0.382	0.340	145
SC536	Arkansas River near Maize	0.308	0.270	144
SC758	Arkansas River at Wichita	0.187	0.130	29

In general, TP concentrations in the Arkansas River from Hutchinson to Wichita are higher during periods of higher flow conditions (0-25%) at all SC stations (**Figure 14**). For example, at the highest flow condition of 0-10% flow exceedance, Hutchinson (SC523) mean and median TP concentrations are 0.660 and 0.530 mg/L, respectively; at 11-25% flow exceedance, Hutchinson (SC523) mean and median TP concentrations are 0.317 and 0.257 mg/L, respectively (**Table 5**). Higher TP concentrations during higher flow conditions can be indicative of nonpoint sources and stormwater runoff. However, variability of TP concentrations at lower flow conditions (76-100%) likely indicates the influence of point sources on TP concentrations. During lower flow conditions, Yoder (SC524) has an elevated mean and median as well as a wider range in TP concentrations when compared to Hutchinson (SC523) and Wichita (SC758). Likewise, the station directly downstream of Yoder (SC524), Maize (SC536), displays a wider range in TP concentrations at lower flow conditions. These elevated TP concentrations and ranges are likely due to the influence of municipal point sources near Yoder (SC524).

Figure 14. Total phosphorus by percent flow exceedance in the Arkansas River, March 19, 1990 to April 18, 2017.

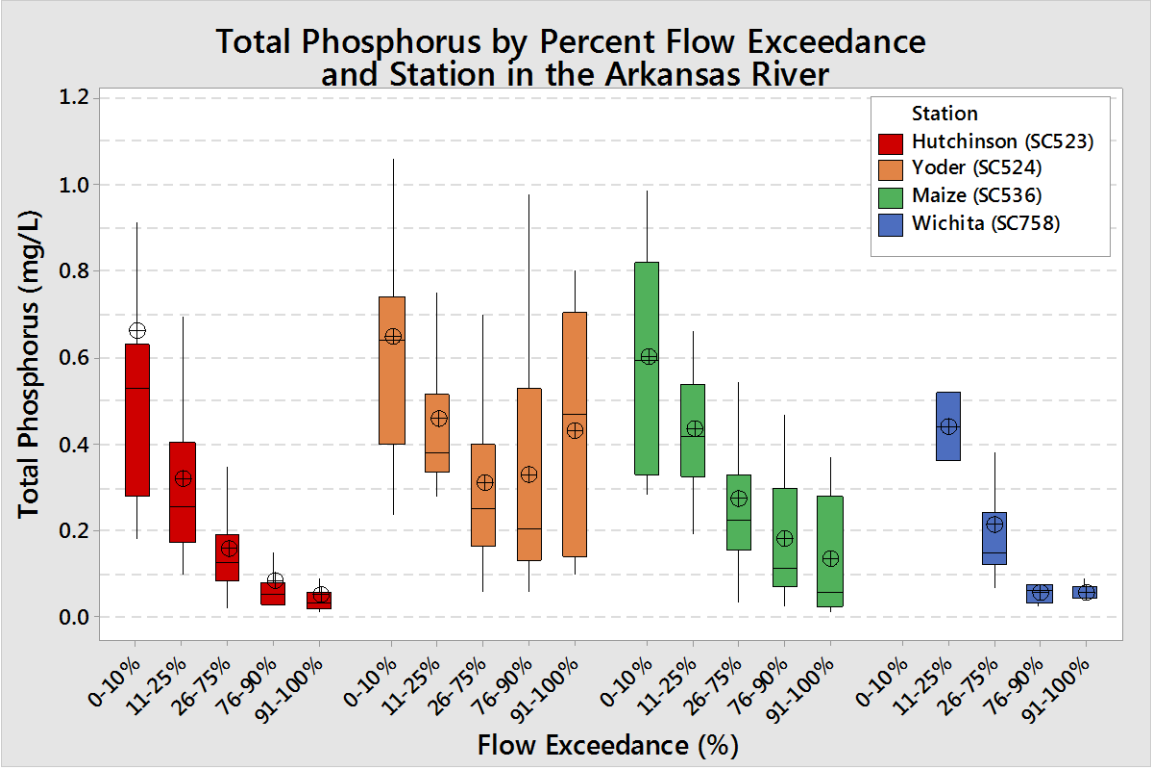


Table 5. Mean, median, and sample size (N) for total phosphorus by percent flow exceedance, season (spring: April through June, summer-fall: July through October, winter: November through March) and station in the Arkansas River, March 19, 1990 to April 18, 2017. Values with no data are denoted with a – symbol.

Flow Exceedance (%)	Total Phosphorus (mg/L)											
	Spring			Summer-Fall			Winter			All Seasons		
	Mean	Median	N	Mean	Median	N	Mean	Median	N	Mean	Median	N
Hutchinson (SC523)												
0-10	0.615	0.495	6	0.541	0.588	6	0.992	0.396	3	0.660	0.530	15
11-25	0.318	0.274	9	0.391	0.280	7	0.250	0.180	8	0.317	0.257	24
26-75	0.221	0.170	15	0.152	0.135	23	0.128	0.109	34	0.155	0.124	72
76-90	0.139	0.074	6	0.044	0.038	6	0.071	0.050	11	0.082	0.050	23
91-100	0.055	0.055	1	0.072	0.035	5	0.027	0.027	5	0.050	0.031	11
0-100	**0.290**	**0.246**	**37**	**0.215**	**0.150**	**47**	**0.168**	**0.107**	**61**	**0.215**	**0.148**	**145**
Yoder (SC524)												
0-10	0.629	0.569	8	0.715	0.678	5	0.591	0.750	3	0.649	0.638	16
11-25	0.488	0.443	9	0.443	0.390	7	0.424	0.370	6	0.456	0.379	22
26-75	0.369	0.264	13	0.412	0.397	23	0.227	0.190	37	0.310	0.250	73
76-90	0.282	0.168	5	0.303	0.231	7	0.370	0.276	10	0.329	0.203	22
91-100	0.484	0.484	2	0.468	0.520	5	0.362	0.195	5	0.427	0.470	12
0-100	**0.449**	**0.359**	**37**	**0.438**	**0.410**	**47**	**0.299**	**0.235**	**61**	**0.382**	**0.340**	**145**
Maize (SC536)												
0-10	0.544	0.525	6	0.661	0.667	6	0.596	0.663	3	0.601	0.592	15
11-25	0.443	0.400	10	0.491	0.437	8	0.347	0.262	6	0.435	0.415	24
26-75	0.332	0.270	15	0.325	0.270	23	0.211	0.170	34	0.273	0.221	72
76-90	0.203	0.148	4	0.107	0.091	4	0.194	0.149	12	0.178	0.113	20
91-100	0.202	0.202	2	0.083	0.048	6	0.163	0.057	5	0.132	0.057	13
0-100	**0.375**	**0.338**	**37**	**0.347**	**0.280**	**47**	**0.237**	**0.192**	**60**	**0.308**	**0.270**	**144**
Wichita (SC758)												
0-10	–	–	–	–	–	–	–	–	–	–	–	–
11-25	0.439	0.439	2	0.440	0.440	1	–	–	–	0.439	0.440	3
26-75	0.190	0.150	5	0.361	0.206	5	0.124	0.125	7	0.213	0.150	17
76-90	0.071	0.071	1	–	–	–	0.049	0.047	3	0.055	0.059	4
91-100	–	–	–	0.060	0.050	3	0.042	0.042	2	0.053	0.044	5
0-100	**0.237**	**0.215**	**8**	**0.270**	**0.170**	**9**	**0.092**	**0.088**	**12**	**0.187**	**0.130**	**29**

Sources of TP contributions to the Arkansas River are also evident in the magnitude and variability of TP concentrations in individual stream samples when percent flow exceedance is greater than 50% (**Figures 15-18**). The stations near Hutchinson (SC523) and at Wichita (SC758) display a distinct trend of decline in TP concentrations from higher to lower flow conditions (**Figures 15 and 18**), indicating nonpoint source influenced watersheds, while sample TP concentrations near Yoder (SC524) and Maize (SC536) remain elevated (**Figures 16-17**). The increase in magnitude and variability of TP concentrations in samples collected under lower flow conditions are indicative of municipal point source loading and are particularly well-defined in the river downstream of Hutchinson as measured at Yoder (SC524). The municipal discharge influencing low flow TP concentrations observed near Yoder (SC524) appears to influence downstream concentrations similarly.

Figure 15. Total phosphorus by percent flow exceedance near Hutchinson (SC523) in the Arkansas River, March 19, 1990 to April 17, 2017.

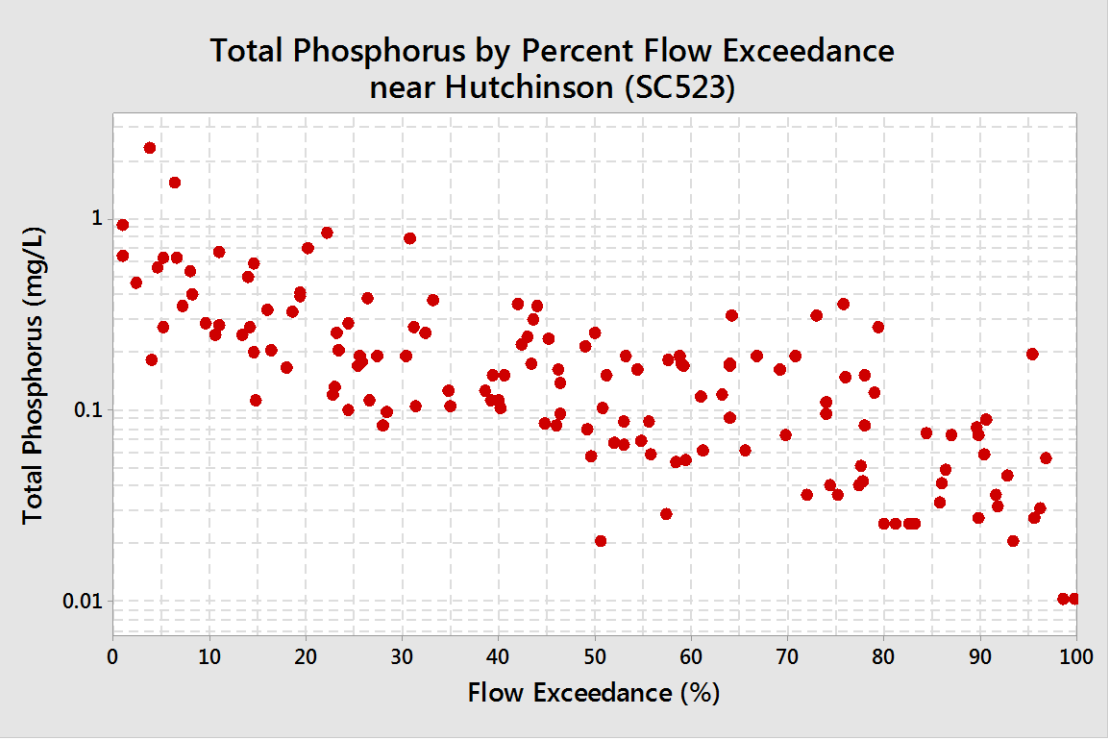


Figure 16. Total phosphorus by percent flow exceedance near Yoder (SC524) in the Arkansas River, March 19, 1990 to April 17, 2017.

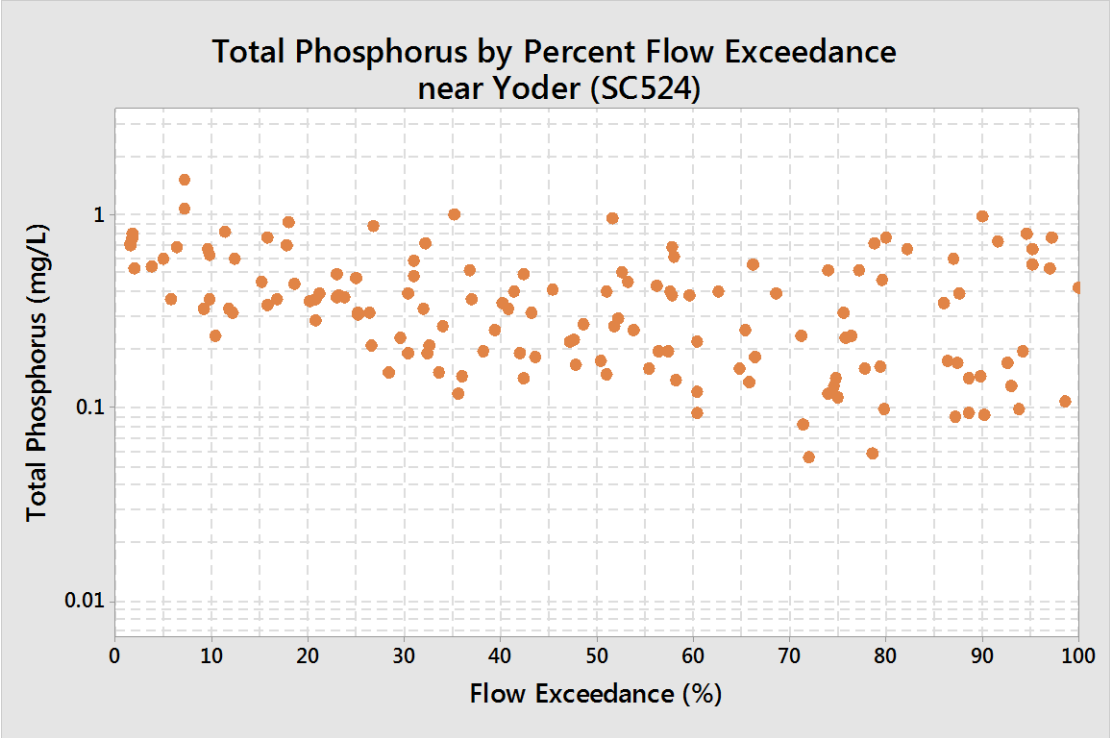


Figure 17. Total phosphorus by percent flow exceedance near Maize (SC536) in the Arkansas River, March 21, 1990 to April 18, 2017.

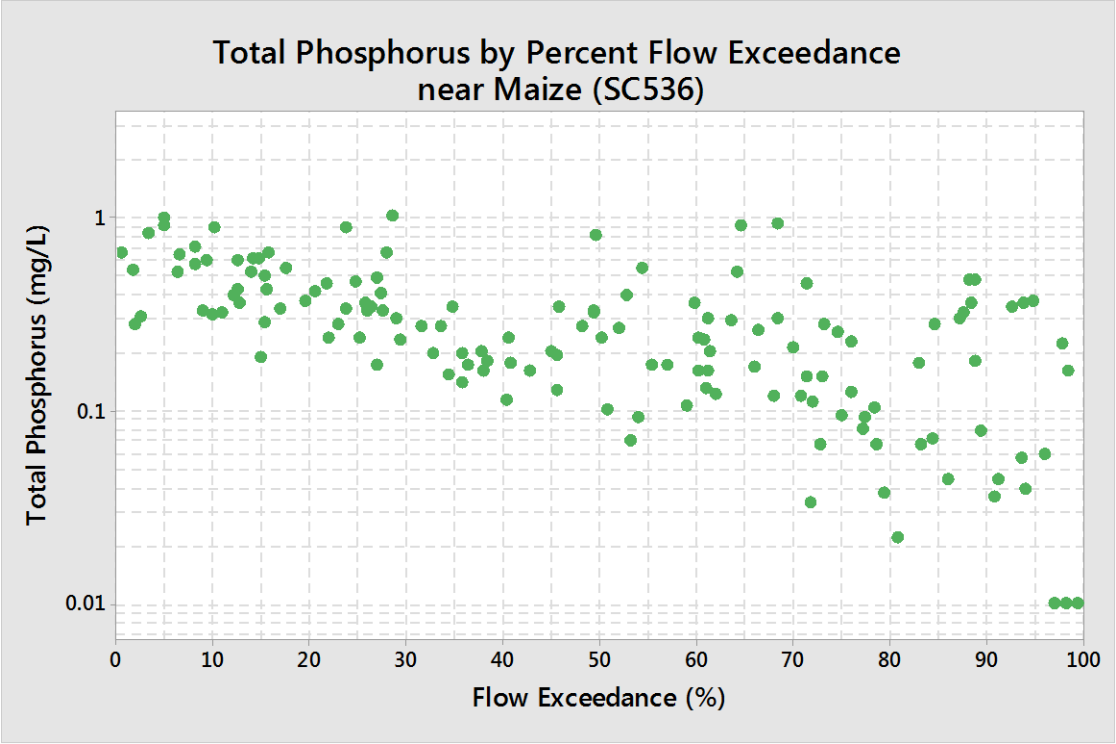
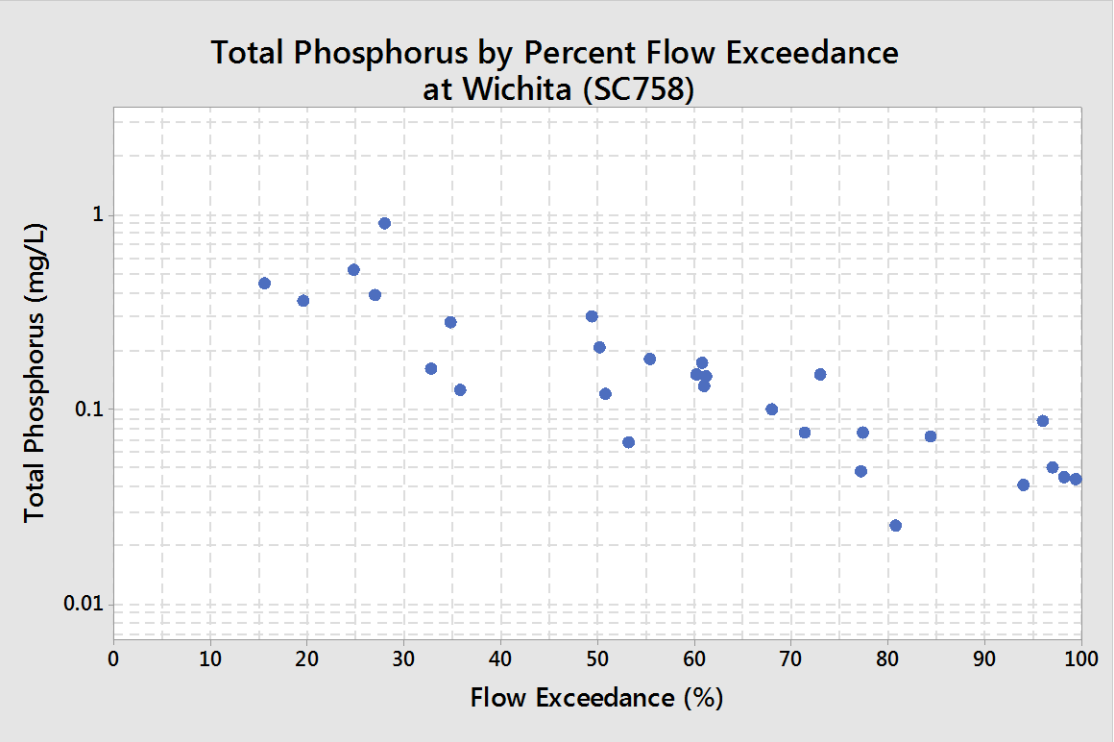
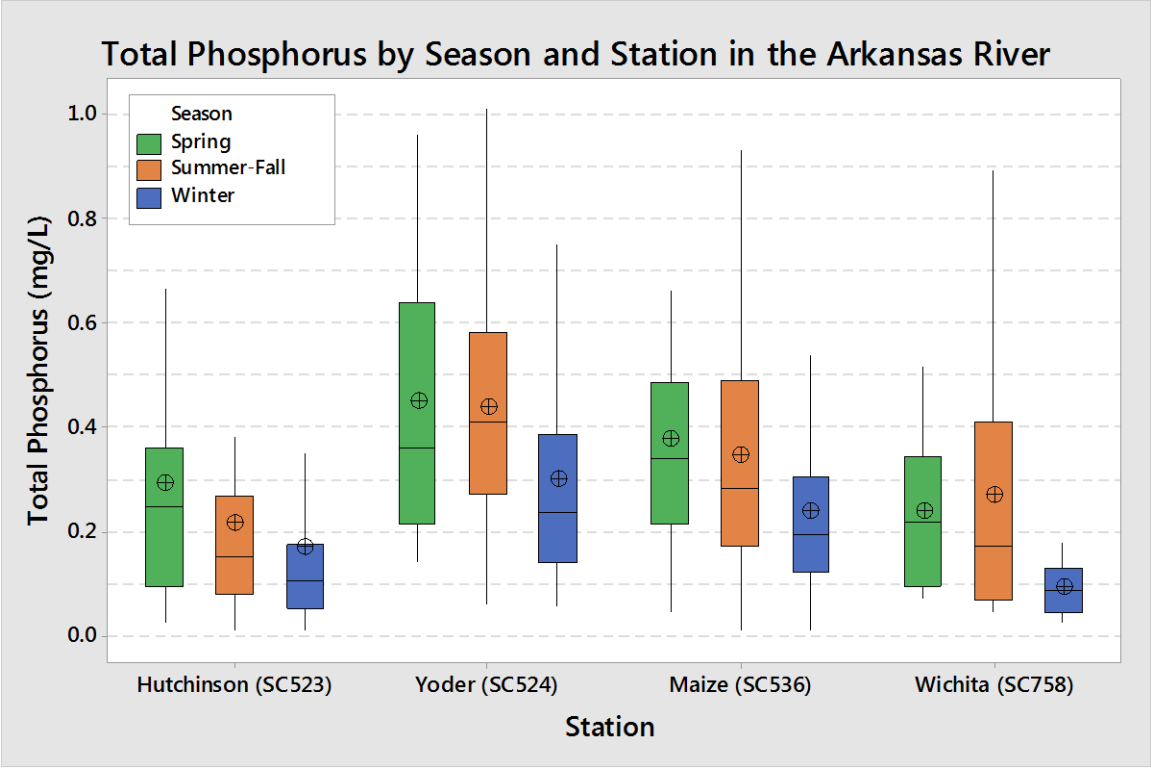


Figure 18. Total phosphorus by percent flow exceedance at Wichita (SC758) in the Arkansas River, March 23, 2010 to April 18, 2017.



Seasonal Assessment: Seasonally, spring (April through June) and summer-fall (July through October) have greater TP means and medians than winter (November through February; **Figure 19**). Spring and winter seasonal variability correspond to higher streamflow during the spring months of May and June and lower streamflow during the winter months of December and January. However, mean and median TP concentrations in the summer-fall are similar to or exceed spring TP concentrations, likely indicating the influence of municipal point sources near Yoder (SC524), Maize (SC536), and Wichita (SC758). Furthermore, Yoder (SC524) and Maize (SC536) have a higher mean and median and a wider range in winter TP concentrations than Hutchinson (SC523), which is upstream of the municipal point source discharges.

Figure 19. Total phosphorus by season and station in the Arkansas River, March 19, 1990 to April 18, 2017.



Annually, the highest mean TP concentrations occurred in: 1993 near Hutchinson (SC523), with a mean of 0.700 mg/L; 1992 near Yoder (SC524), with a mean of 0.718 mg/L; 1990 near Maize (SC536), with a mean of 0.616 mg/L; and 2015 at Wichita (SC758), with a mean of 0.278 mg/L (**Figures 20-23**). The highest median TP concentrations occurred in: 1993 near Hutchinson (SC523), with a median of 0.435 mg/L; 1992 near Yoder (SC524), with a median of 0.760 mg/L; 1990 near Maize (SC536), with a median of 0.540 mg/L; and 2017 at Wichita (SC758), with a median of 0.255 mg/L. The lowest annual mean and median TP concentrations correspond to a pattern of annual low streamflow occurring in the low flow year of 2012 near Hutchinson (SC523), Maize (SC536), and Wichita (SC758; **Table 6**). The station near Yoder (SC524) is the exception, with annual TP concentration lows occurring in 2005. Both the mean and median TP concentrations near Hutchinson (SC523), Yoder (SC524), and Maize (SC536) have declined over the period of record when comparing the 1990 to 1999 with 2000 to 2017 datasets; the largest reduction is a 50% reduction in both mean and median concentrations occurring at Yoder (SC523).

Figure 20. Annual mean and median total phosphorus near Hutchinson (SC523) in the Arkansas River, March 19, 1990 to April 17, 2017.

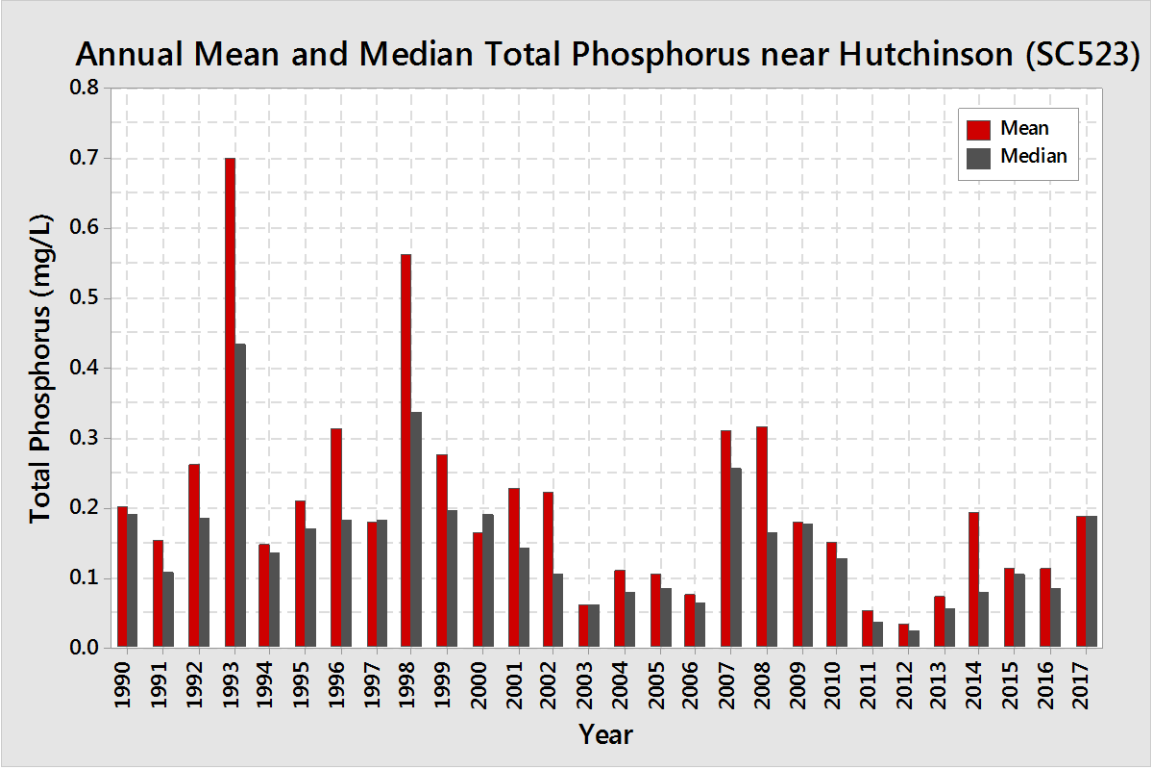


Figure 21. Annual mean and median total phosphorus near Yoder (SC524) in the Arkansas River, March 19, 1990 to April 17, 2017.

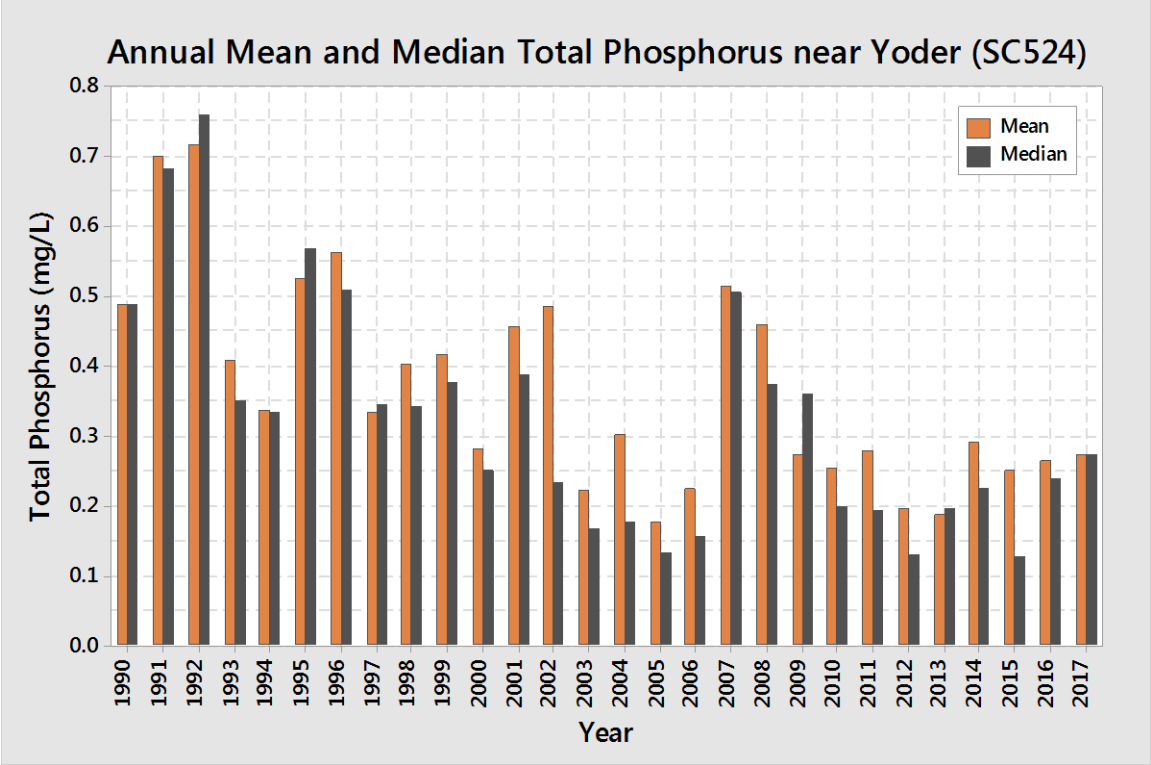


Figure 22. Annual mean and median total phosphorus near Maize (SC536) in the Arkansas River, March 21, 1990 to April 18, 2017.

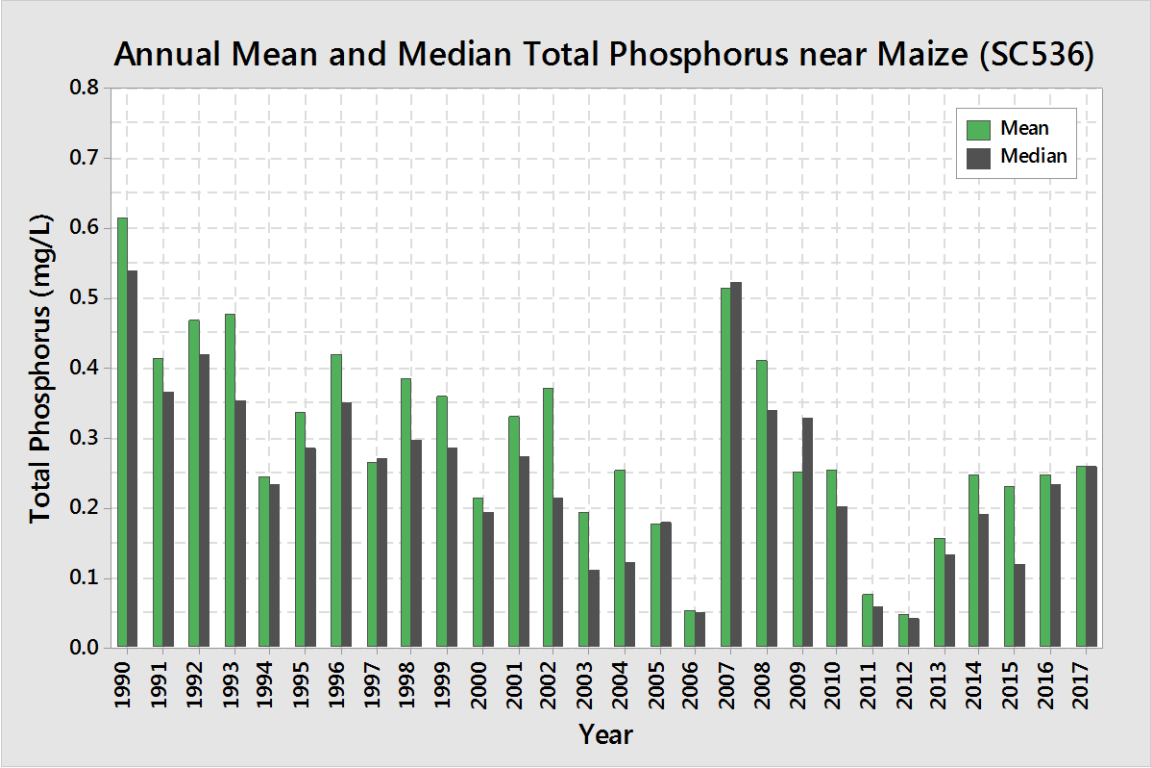


Figure 23. Annual mean and median total phosphorus at Wichita (SC758) in the Arkansas River, March 23, 2010 to April 18, 2017.

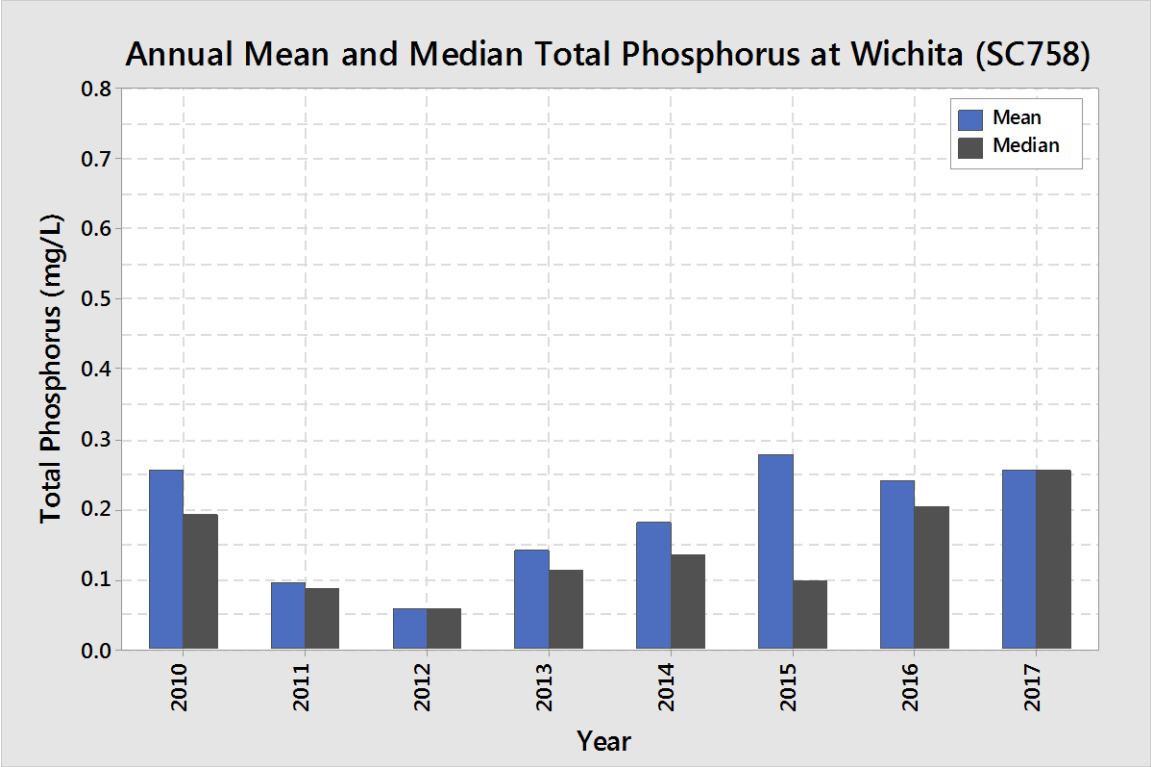


Table 6. Annual mean, median, and sample size (N) for total phosphorus concentrations by station in the Arkansas River. Values with no data are denoted as –.

Year	Total Phosphorus (mg/L)											
	Hutchinson (SC523)			*Yoder (SC524)*			*Maize (SC536)*			*Wichita (SC758)*		
	Mean	Median	N	Mean	Median	N	Mean	Median	N	Mean	Median	N
1990	0.202	0.190	5	0.490	0.490	5	0.616	0.540	5	–	–	0
1991	0.154	0.108	6	0.700	0.685	6	0.413	0.365	6	–	–	0
1992	0.262	0.185	6	0.718	0.760	6	0.468	0.420	6	–	–	0
1993	0.700	0.435	6	0.410	0.350	6	0.478	0.355	6	–	–	0
1994	0.148	0.135	6	0.338	0.335	6	0.245	0.235	6	–	–	0
1995	0.211	0.170	6	0.528	0.570	6	0.338	0.285	6	–	–	0
1996	0.315	0.183	6	0.564	0.508	6	0.419	0.350	6	–	–	0
1997	0.181	0.182	6	0.334	0.345	6	0.264	0.270	6	–	–	0
1998	0.565	0.338	6	0.403	0.342	6	0.386	0.297	6	–	–	0
1999	0.276	0.197	6	0.417	0.377	6	0.360	0.285	6	–	–	0
2000	0.164	0.190	5	0.281	0.250	5	0.213	0.194	5	–	–	0
2001	0.229	0.143	6	0.457	0.389	6	0.330	0.275	6	–	–	0
2002	0.222	0.106	6	0.486	0.234	6	0.371	0.214	6	–	–	0
2003	0.061	0.062	6	0.223	0.169	6	0.195	0.111	6	–	–	0
2004	0.111	0.080	6	0.301	0.177	6	0.253	0.122	6	–	–	0
2005	0.104	0.086	6	0.175	0.135	6	0.176	0.180	5	–	–	0
2006	0.077	0.064	6	0.226	0.156	6	0.054	0.051	6	–	–	0
2007	0.311	0.257	6	0.514	0.506	6	0.515	0.522	6	–	–	0
2008	0.316	0.166	5	0.459	0.375	5	0.412	0.340	5	–	–	0
2009	0.179	0.177	5	0.273	0.359	5	0.252	0.328	5	–	–	0
2010	0.151	0.127	4	0.253	0.198	4	0.254	0.204	4	0.257	0.193	4
2011	0.053	0.035	3	0.278	0.194	3	0.077	0.060	3	0.095	0.087	3
2012	0.034	0.025	4	0.197	0.130	4	0.046	0.041	4	0.058	0.058	4
2013	0.073	0.057	4	0.187	0.196	4	0.157	0.133	4	0.141	0.114	4
2014	0.193	0.080	4	0.290	0.225	4	0.248	0.190	4	0.181	0.135	4
2015	0.113	0.105	4	0.252	0.127	4	0.231	0.120	4	0.278	0.099	4
2016	0.114	0.084	4	0.265	0.240	4	0.248	0.235	4	0.243	0.205	4
2017	0.187	0.187	2	0.275	0.275	2	0.260	0.260	2	0.255	0.255	2
1990 to 1999	***0.301***	***0.184***	***59***	***0.490***	***0.434***	***59***	***0.399***	***0.324***	***59***	***–***	***–***	***0***
2000 to 2017	***0.150***	***0.096***	***86***	***0.300***	***0.212***	***86***	***0.238***	***0.192***	***85***	***0.188***	***0.125***	***29***

Individual TP samples can indicate sources of TP loading in these watersheds by comparing samples collected on concurrent days at upstream and downstream stations. Samples collected near upstream Hutchinson (SC523) and downstream Yoder (SC524) indicate that higher TP concentrations are detected near Yoder (SC524; **Figure 24**). Samples collected near upstream Yoder (SC524) and at downstream Maize (SC536) also indicate that higher TP concentrations are detected near Yoder (SC524), though there are a limited number of samples for this dataset (**Figure 25**). Concurrent day samples collected at upstream Maize (SC536) and downstream Wichita (SC758) display TP concentrations that increase consistently at both stations, indicating that there is no dominant source of TP loading for these watersheds (**Figure 26**).

Figure 24. Total phosphorus at upstream Hutchinson (SC523) versus downstream Yoder (SC524) stations for concurrent day samples in the Arkansas River, March 19, 1990 to April 17, 2017.

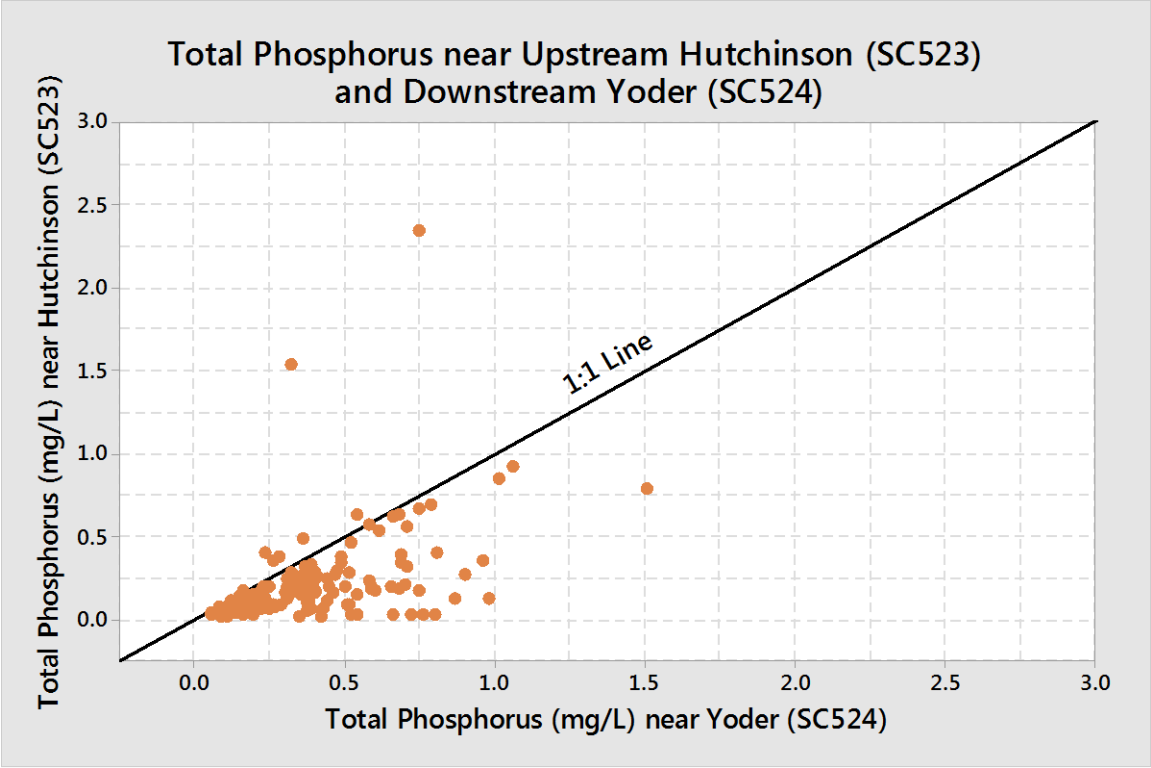


Figure 25. Total phosphorus at upstream Hutchinson (SC523) versus downstream Yoder (SC524) stations for concurrent day samples in the Arkansas River, April 20, 2004 to July 7, 2009.

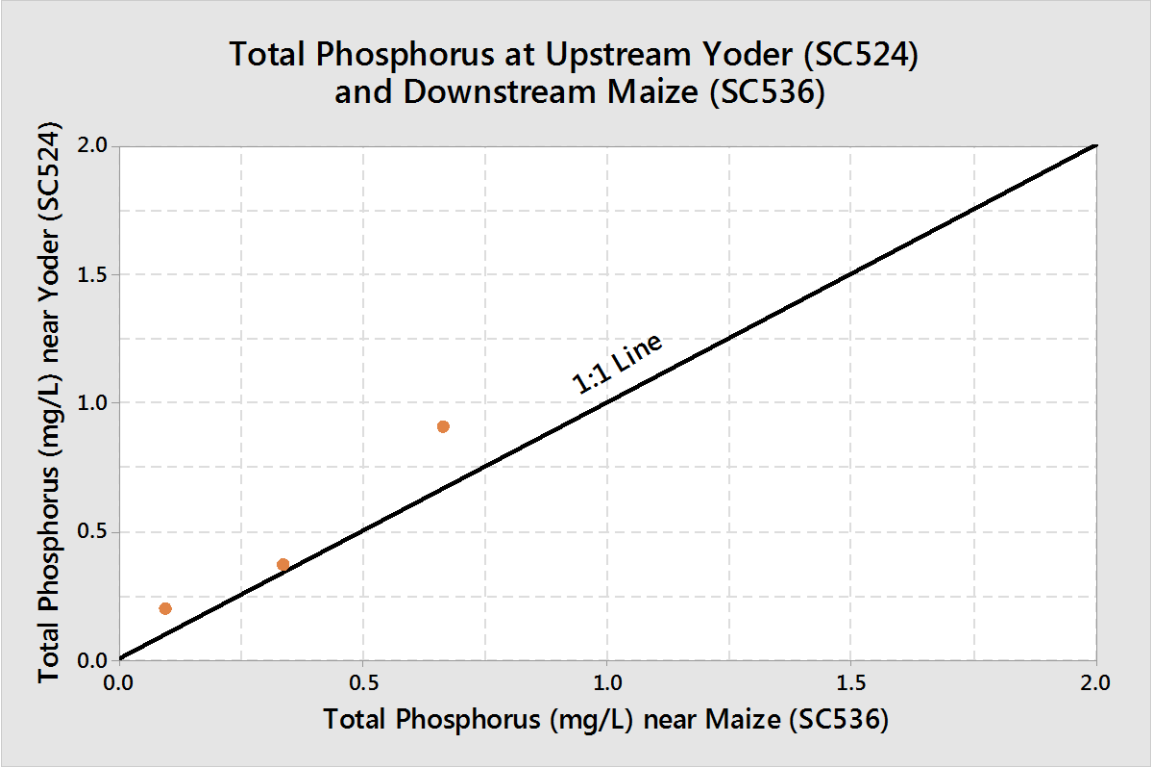
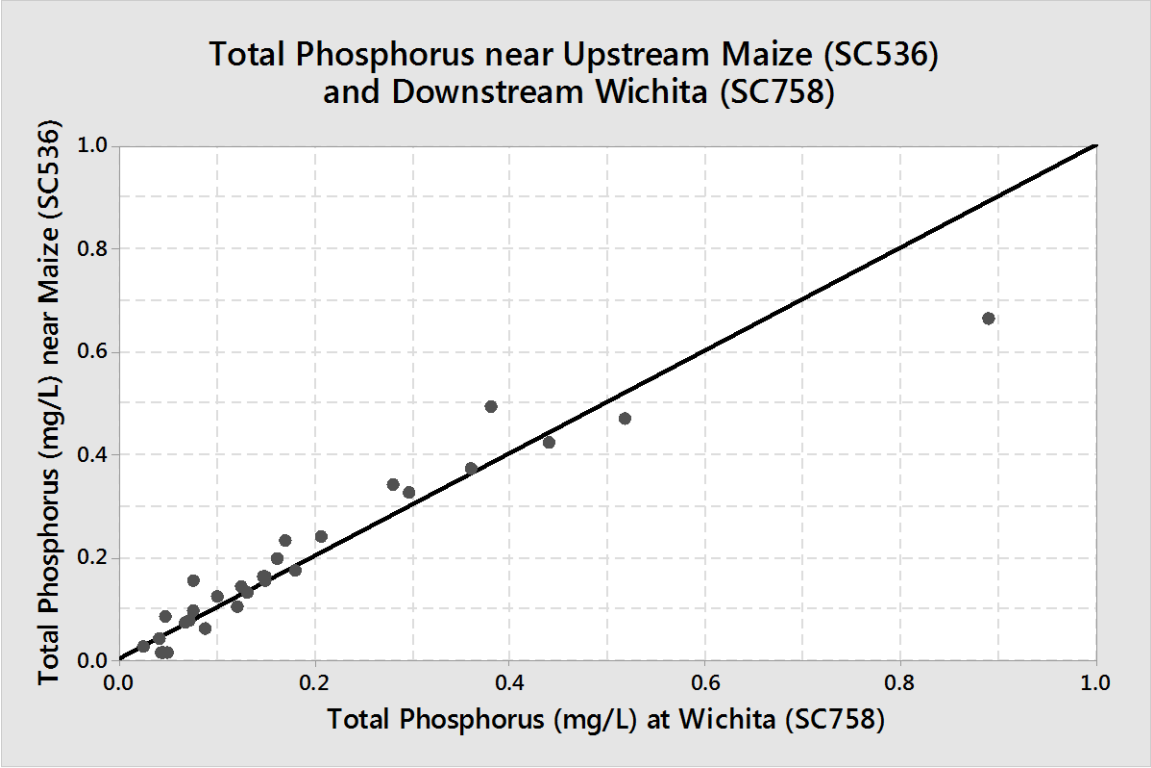


Figure 26. Total phosphorus at upstream Hutchinson (SC523) versus downstream Yoder (SC524) stations for concurrent day samples in the Arkansas River, March 23, 2010 to April 18, 2017.



Total Phosphorus and Other Water Quality Parameters: Orthophosphate (OP) is the soluble portion of TP that is readily available for biological use. It is commonly found in higher concentrations in the discharge of municipal wastewater treatment plants (WWTP), and can therefore be indicative of point source contributions of phosphorus in streams. Only samples measuring above the reporting limit are included in the concentration means displayed in **Table 7**, resulting in a left censored data set which overestimates true OP concentration means. In addition, reporting limits for OP have changed throughout the period of record: 0.01 mg/L from 1995-1996, 0.02 mg/L from 1997 to February 2002, and 0.25 from March 2002 to 2017.

Despite these limitations and variability, Yoder (SC524) has consistently maintained the highest percentage of samples detected above the reporting limit, as well as the highest censored mean OP concentrations throughout the various periods with differing reporting limits. There are few individual instances of OP concentrations exceeding 0.4 mg/L for the period of record (**Figures 27-30)**. The only stations to exceed 0.4 mg/L OP are Yoder (SC524) and Maize (SC536), which are also the stations with the most frequent OP detections. Elevated OP concentrations at these stations is indicative of point source influence, likely due to the contribution of municipal WWTP effluent.

Table 7. Mean detected orthophosphate (OP) samples and the percentage of the samples greater than analytical reporting limit (> RL) separated by reporting limit increases in the Arkansas River, February 6, 1995 to November 3, 2015. Values with no data are denoted with a – symbol.

Station	Sample Information	Period of Record			
		1995-1996 (0.01 mg/L)	1997-Feb. 2002 (0.02 mg/L)	Mar. 2002-2015 (0.25 mg/L)	1990-2015
Hutchinson (SC523)	Mean (mg/L)	0.112	0.047	0.330	0.131
	N	8	3	2	13
	Sample Percent > RL	67	19	3	14
Yoder (SC524)	Mean (mg/L)	0.210	0.119	0.352	0.241
	N	12	7	11	30
	Sample Percent > RL	100	44	16	31
Maize (SC536)	Mean (mg/L)	0.161	0.070	0.329	0.195
	N	9	5	7	21
	Sample Percent > RL	75	31	11	22
Wichita (SC758)	Mean (mg/L)	-	-	0.318	0.318
	N	-	-	2	2
	Sample Percent > RL	-	-	9	9

Figure 27. Orthophosphate and total phosphorus samples measuring greater than the reporting limit near Hutchinson (SC523) in the Arkansas River, February 6, 1995 to November 3, 2015.

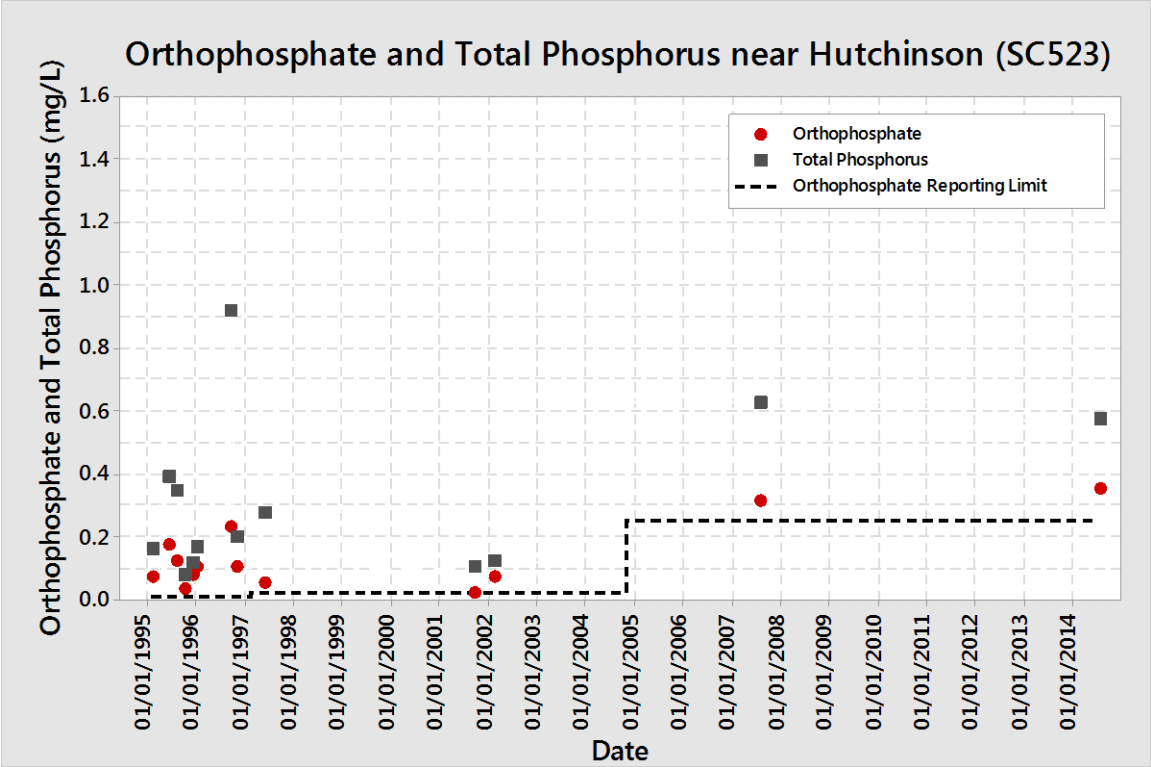


Figure 28. Orthophosphate and total phosphorus samples measuring greater than the reporting limit near Yoder (SC524) in the Arkansas River, February 6, 1995 to November 3, 2015.

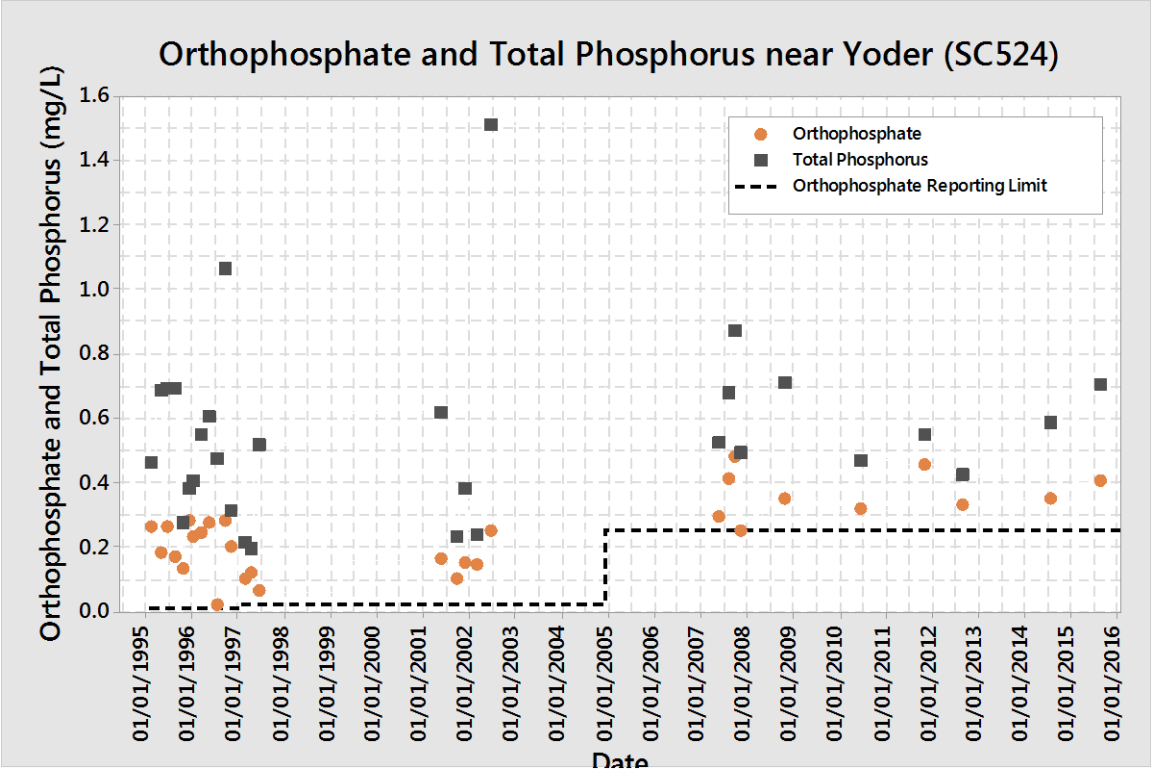


Figure 29. Orthophosphate and total phosphorus samples measuring greater than the reporting limit near Maize (SC536) in the Arkansas River, February 6, 1995 to November 3, 2015.

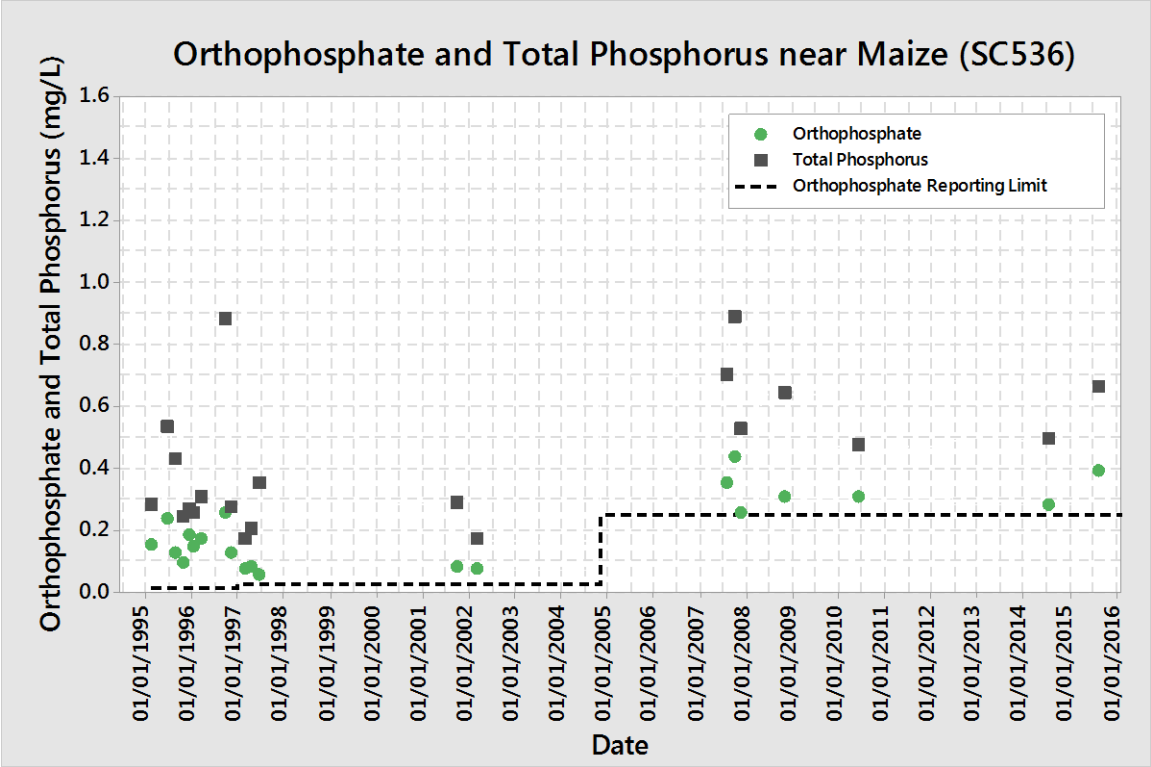
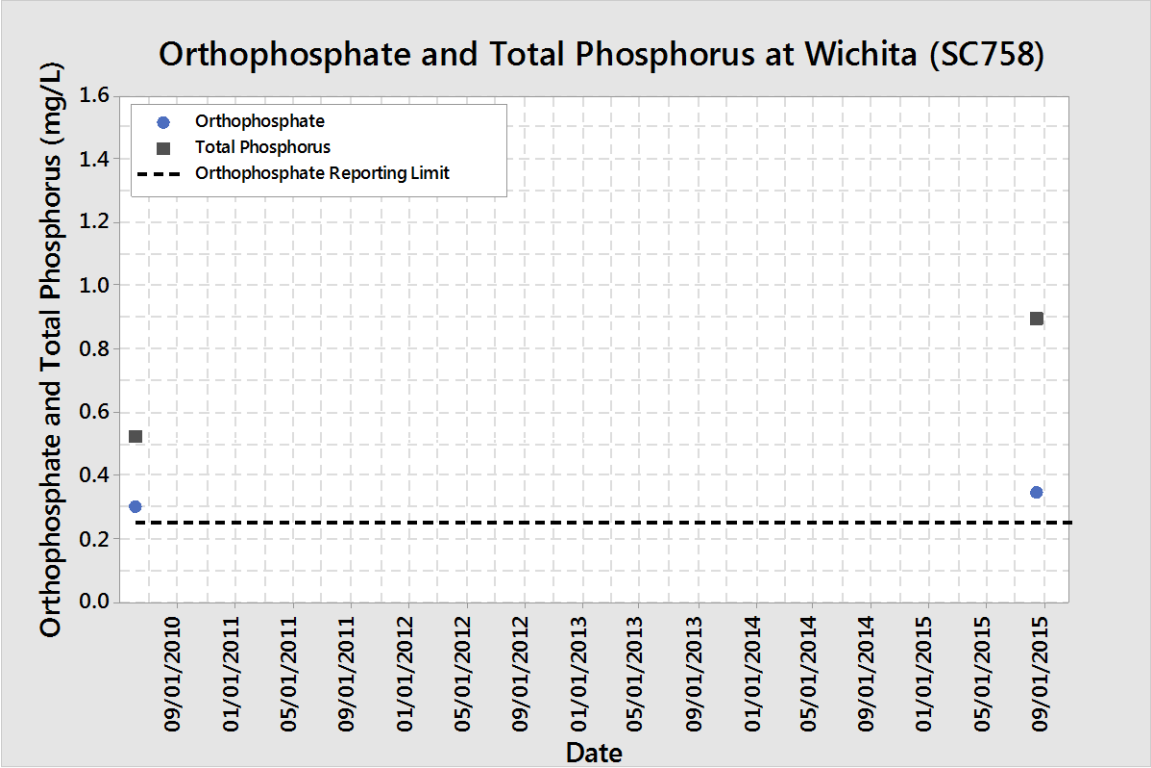
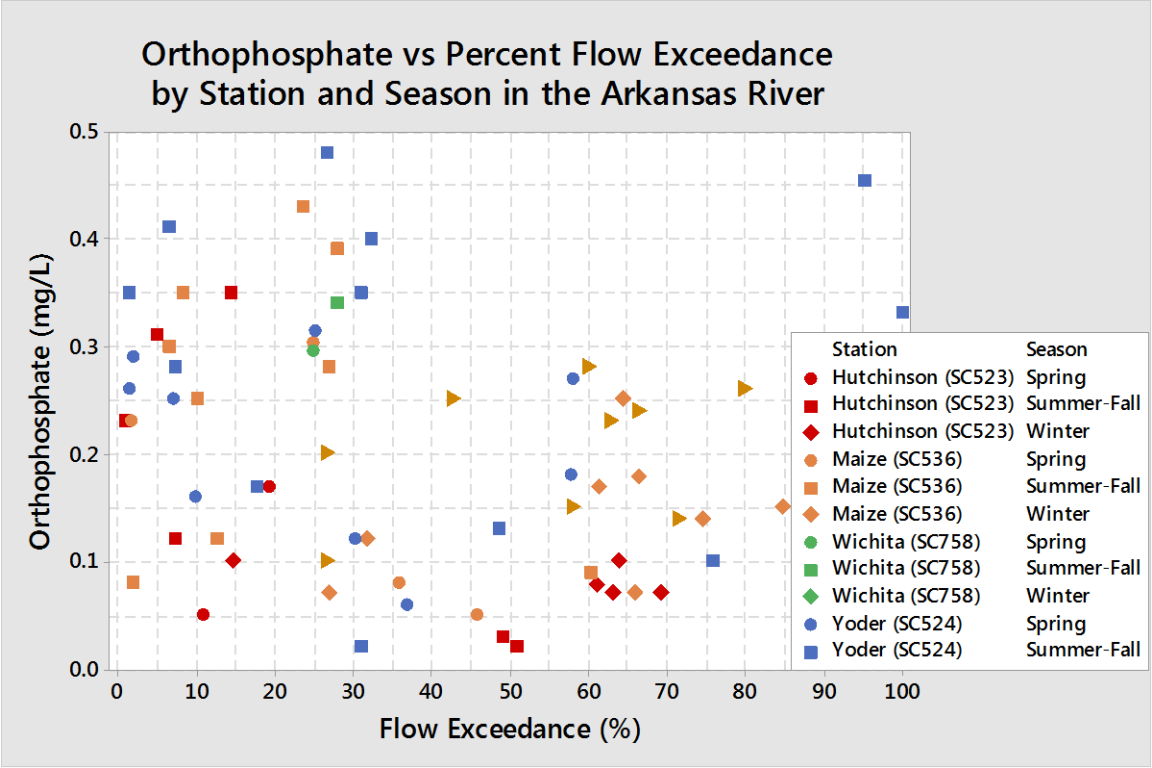


Figure 30. Orthophosphate and total phosphorus samples measuring greater than the reporting limit at Wichita (SC758) in the Arkansas River, June 2, 2010 to November 3, 2015.



Further indication of municipal WWTP influence is evident during various flow conditions and seasons. Detections of OP are generally highest during above normal flow conditions in the spring and summer-fall (**Figure 31**), which is indicative of nonpoint sources and stormwater runoff; the exception to this are two summer-fall detections near Yoder (SC524) during lower flow conditions which have OP concentrations similar to those at higher flow conditions and are indicative of point source loading. Detected OP concentrations are lowest during normal flows, which predominantly occur in the winter. During normal flow conditions, Yoder (SC524) and Maize (SC536) display OP concentrations during the summer-fall and winter that can be two to three times the concentrations seen at Hutchinson (SC523).

Figure 31. Orthophosphate versus percent flow exceedance by station and season in the Arkansas River, February 6, 1995 to November 3, 2015.



Phosphorus has a high affinity for fixation in soils, where it is adsorbed from soil solution. Erosion of phosphorus-laden soil particles is a common means for phosphorus to enter streams. Due to the low concentration of phosphorus in freshwater, it is then desorbed. This propensity for adsorbtion and desorbtion to soil particles creates a relationship between TP and total suspended solids (TSS) that is evident at all stations in the Arkansas River (**Figures 32-35**). This relationship is especially well-defined during above normal (0-25%) and normal (26-75%) flow conditions; however, during below normal (76-100%) flow conditions near Yoder (SC524) and Maize (SC536), which are influenced by point sources, TP and TSS have less of a correlation as TP concentration increases irrespective of TSS concentration.

Figure 32. Total phosphorus versus total suspended solids and total phosphorus versus total suspended solids and percent flow exceedance near Hutchinson (SC523) in the Arkansas River, March 19, 1990 to April 17, 2017.

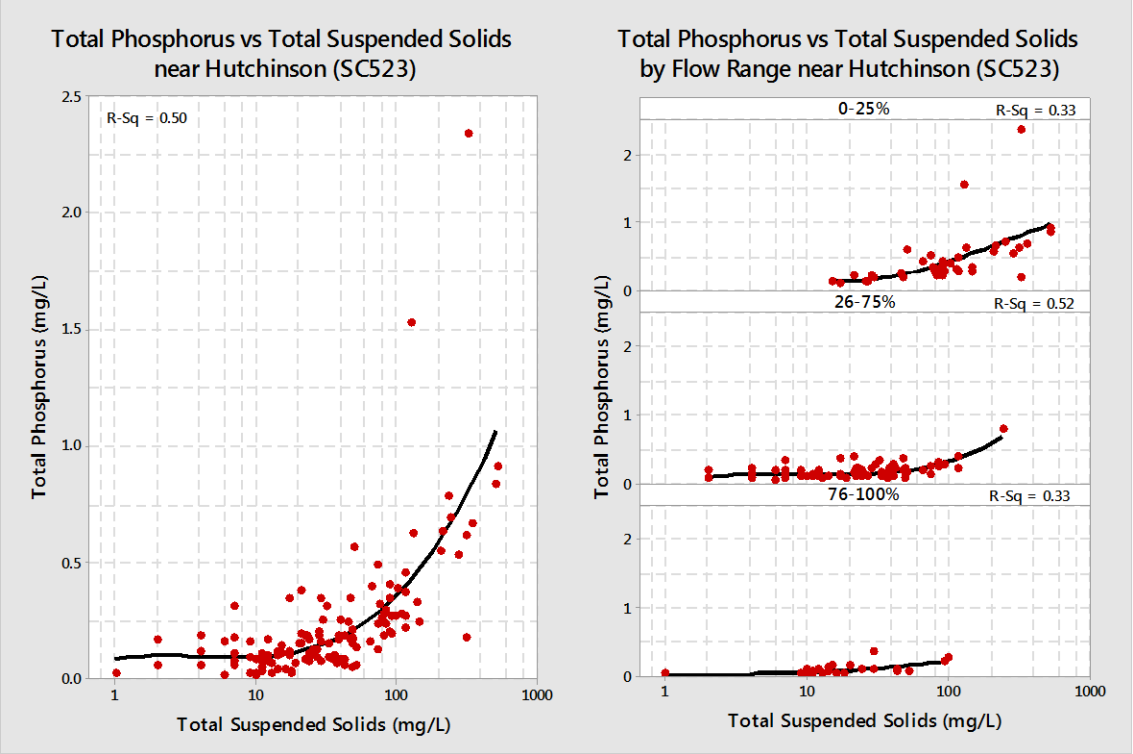


Figure 33. Total phosphorus versus total suspended solids and total phosphorus versus total suspended solids and percent flow exceedance near Yoder (SC524) in the Arkansas River, March 19, 1990 to April 17, 2017.

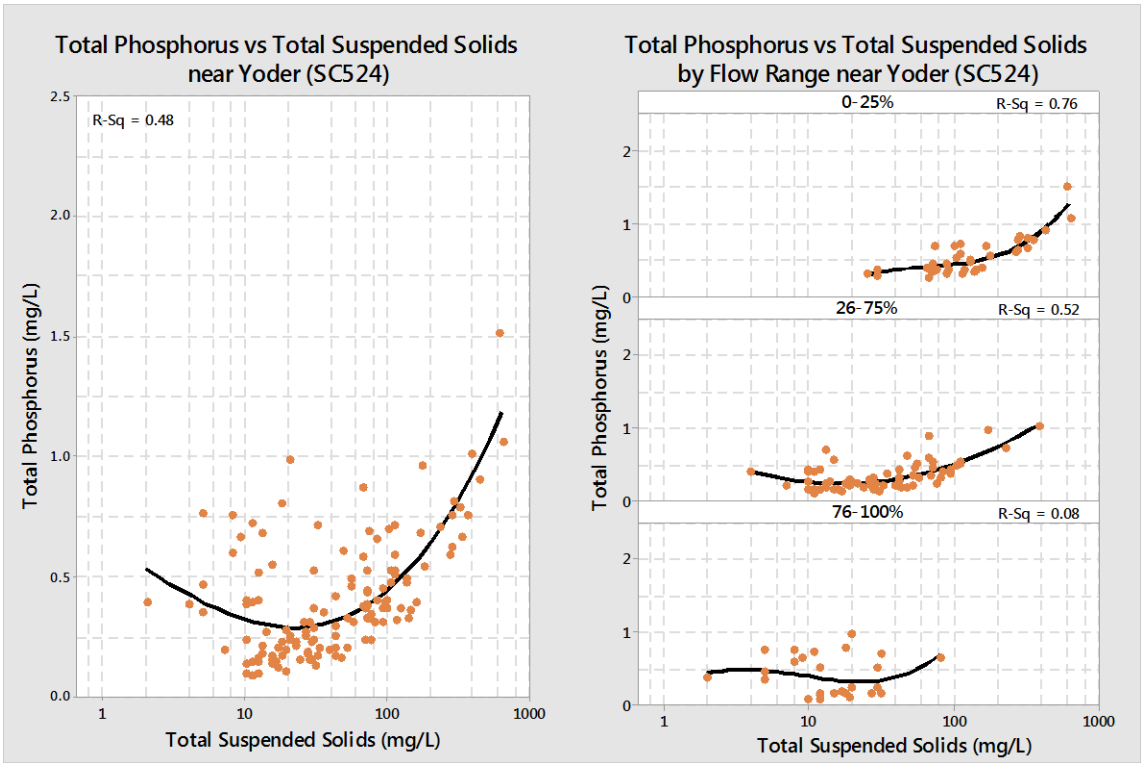


Figure 34. Total phosphorus versus total suspended solids and total phosphorus versus total suspended solids and percent flow exceedance near Maize (SC536) in the Arkansas River, March 21, 1990 to April 18, 2017.

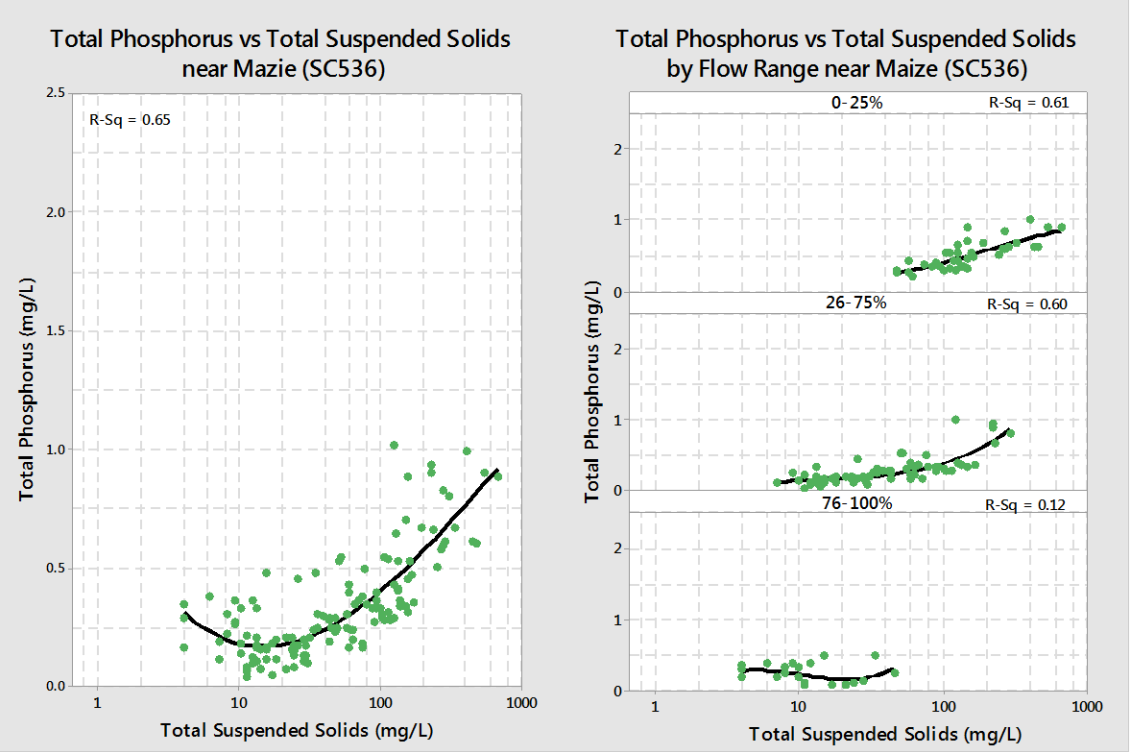
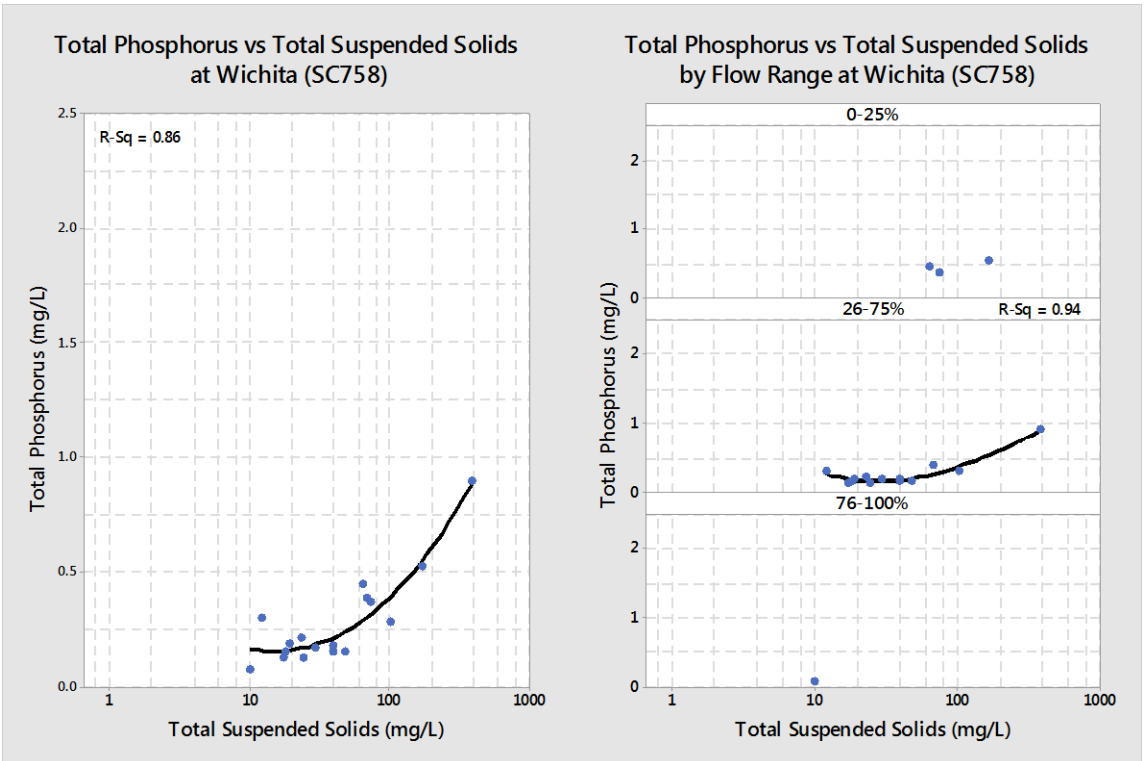


Figure 35. Total phosphorus versus total suspended solids and total phosphorus versus total suspended solids and percent flow exceedance at Wichita (SC758) in the Arkansas River, March 23, 2010 to April 18, 2017.



Total Phosphorus and Major Point Source Contributions: The previous analyses and discussions indicate that TP concentrations in the Arkansas River have dominant sources of TP upstream of Yoder (SC524). The Hutchinson WWTP and South Hutchinson WWTP are both major municipal sources of TP that discharge to the Arkansas River upstream of this station. The influence of these WWTPs' effluents in the Yoder (SC524) watershed was evaluated by comparing the monthly TP concentrations in the effluent of the Hutchinson WWTP (**Figure 36**) and South Hutchinson WWTP (**Figure 37**) to the monthly TP concentrations in the Arkansas River near Yoder (SC524), where concomitant data were available. The concurrence is strongest for Yoder (SC524) and the South Hutchinson WWTP, which has TP concentrations up to seven times higher than the Hutchinson WWTP.

Figure 36. Total phosphorus effluent from Hutchinson Wastewater Treatment Plant (NPDES Permit #KS0036188) contributed to the Arkansas River upstream of Yoder (SC524), January 2003 to January 2017.

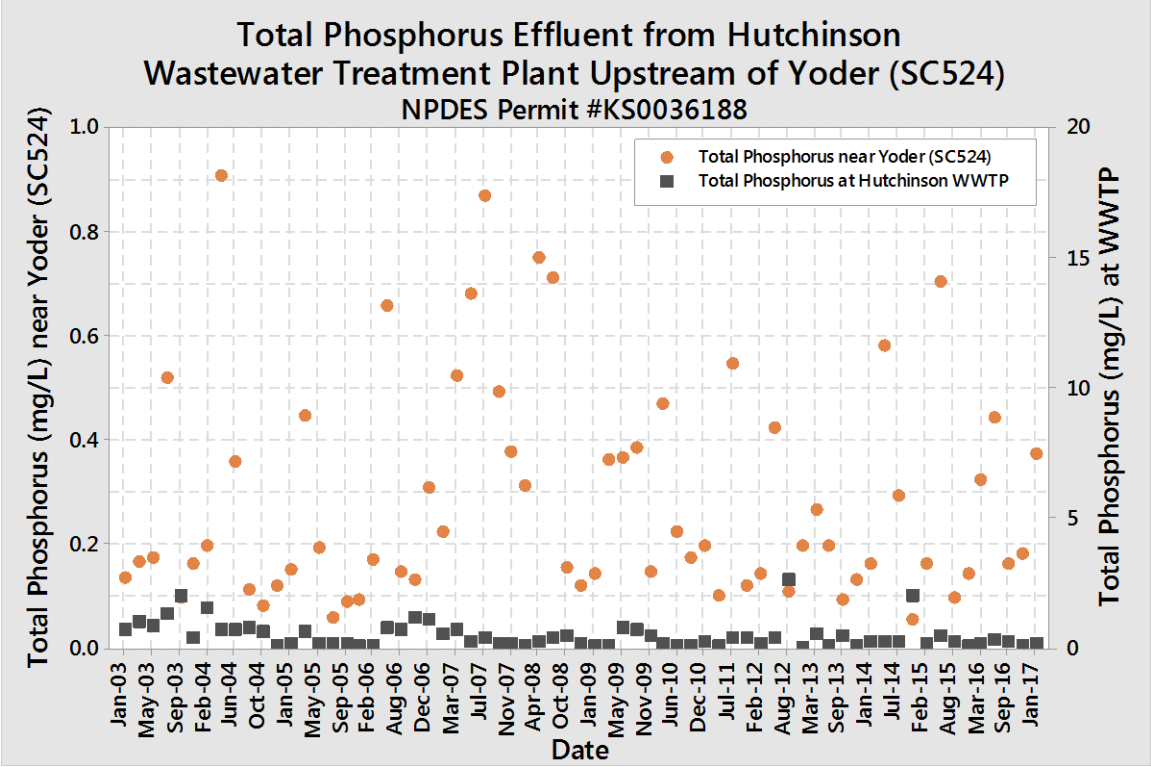
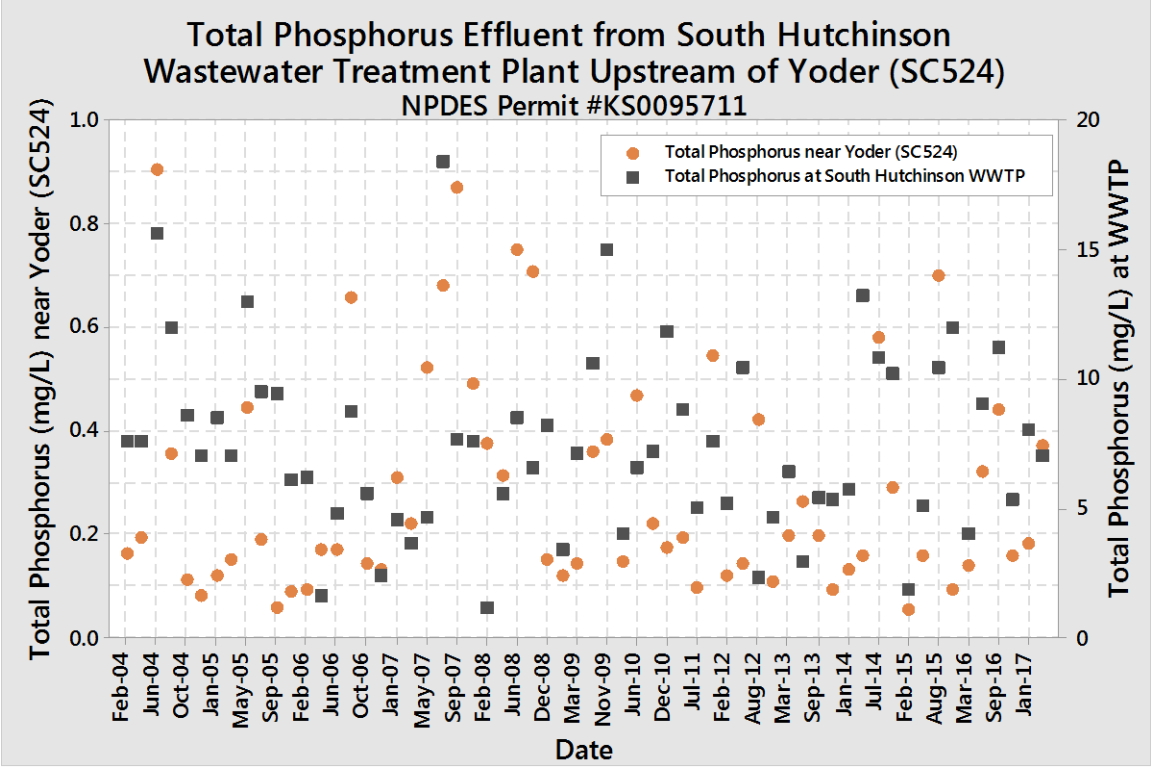


Figure 37. Total phosphorus effluent from South Hutchinson Wastewater Treatment Plant (NPDES Permit #KS0095711) contributed to the Arkansas River upstream of Yoder (SC524), February 2004 to April 2017.



Total Phosphorus and Biological Indicators: The narrative criteria of the Kansas Surface Water Quality Standards are based on conditions of the prevailing biological community. Excessive primary productivity may be indicated by extreme shifts in dissolved oxygen (DO), dissolved oxygen saturation (DO saturation), and pH as the chemical reactions of photosynthesis and respiration alter the ambient levels of oxygen and acid-base balance of the stream. These extreme shifts, in turn, can result in undesirable regime shifts in the biological community within the stream.

Dissolved oxygen and temperature are inversely related at all sites in the Arkansas River (**Figures 38-41**). This corresponds to seasonal changes in DO and temperature, where low mean DO concentrations occur in spring and summer-fall, when temperatures are highest, and high mean DO concentrations occur in winter, when temperatures are lowest (**Table 8**). This relationship is expected because oxygen becomes less soluble in water as temperatures increase. However, the weakest correlation occurs at Yoder (SC524), where DO concentrations become more variable at higher temperatures and can even reach concentrations seen at much lower temperatures (**Figure 39**). The only station with an excursion below the water quality criterion of 5 mg/L is Maize (SC536), which recorded a DO concentration of 3.20 mg/L in May of 1990 (**Figure 40**).

Figure 38. Dissolved oxygen and the relationship between dissolved oxygen and temperature near Hutchinson (SC523) in the Arkansas River, March 19, 1990 to April 17, 2017.

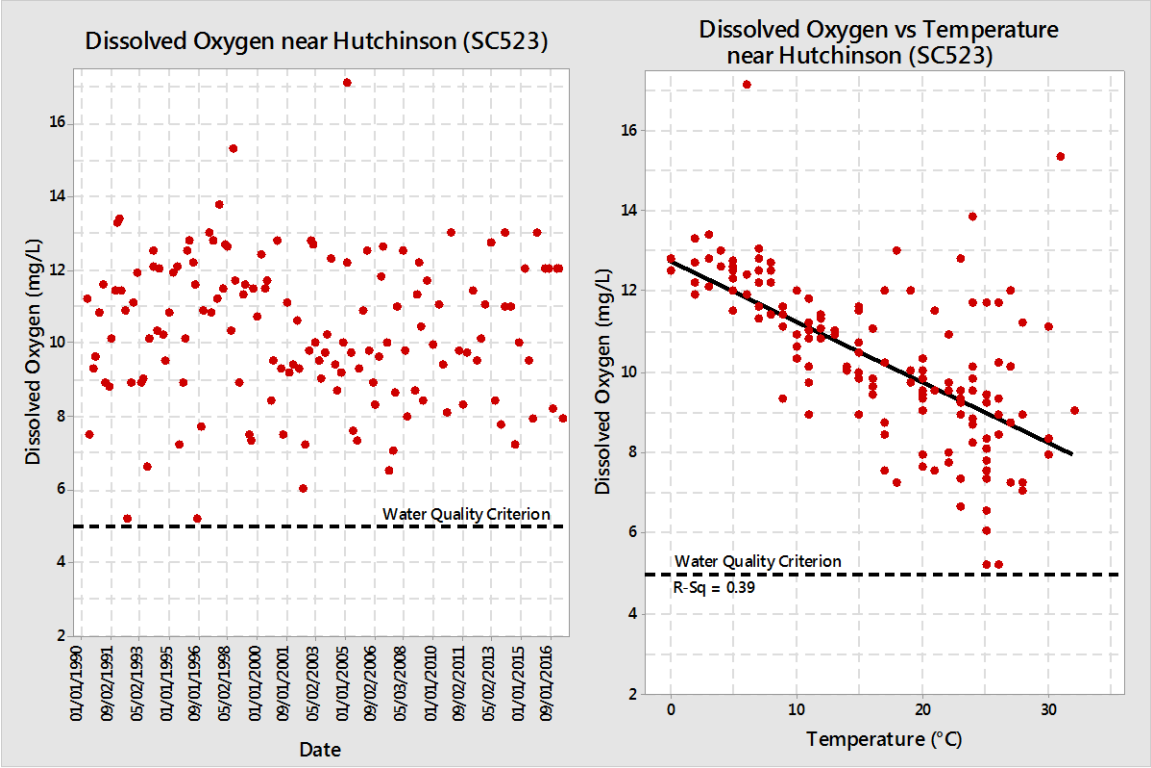


Figure 39. Dissolved oxygen and the relationship between dissolved oxygen and temperature near Yoder (SC524) in the Arkansas River, March 19, 1990 to April 17, 2017.

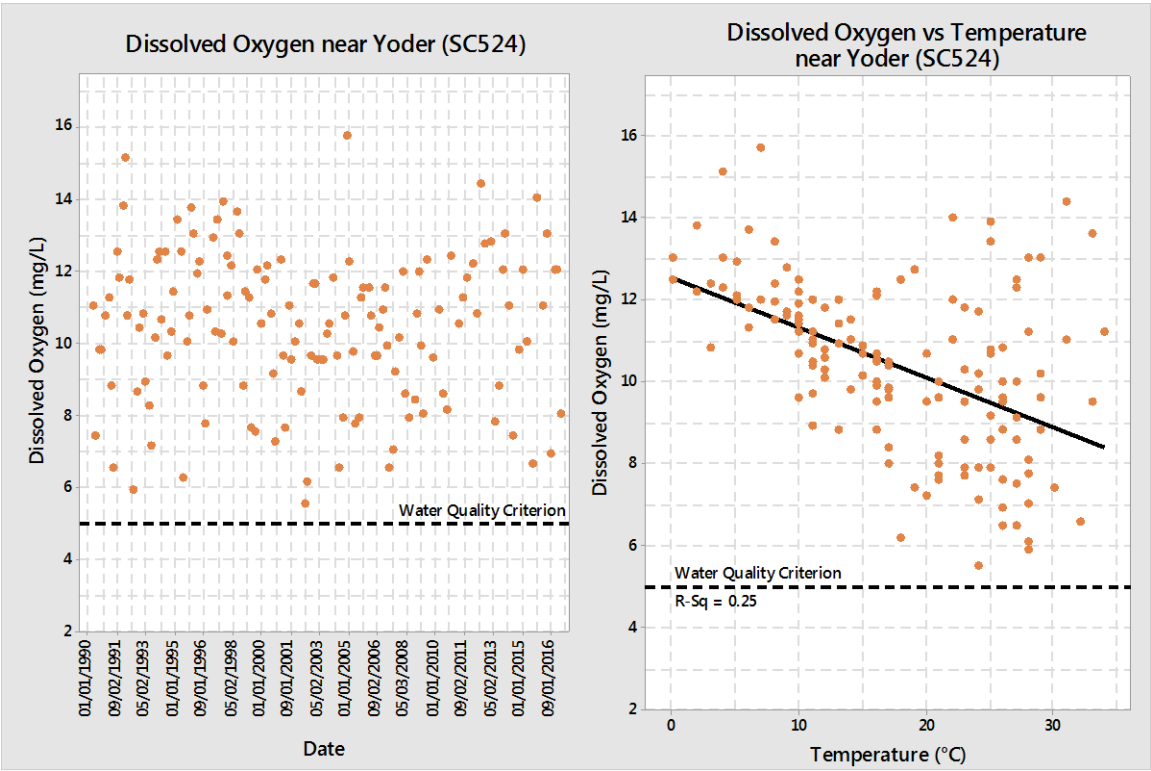


Figure 40. Dissolved oxygen and the relationship between dissolved oxygen and temperature near Maize (SC536) in the Arkansas River, March 21, 1990 to April 18, 2017.

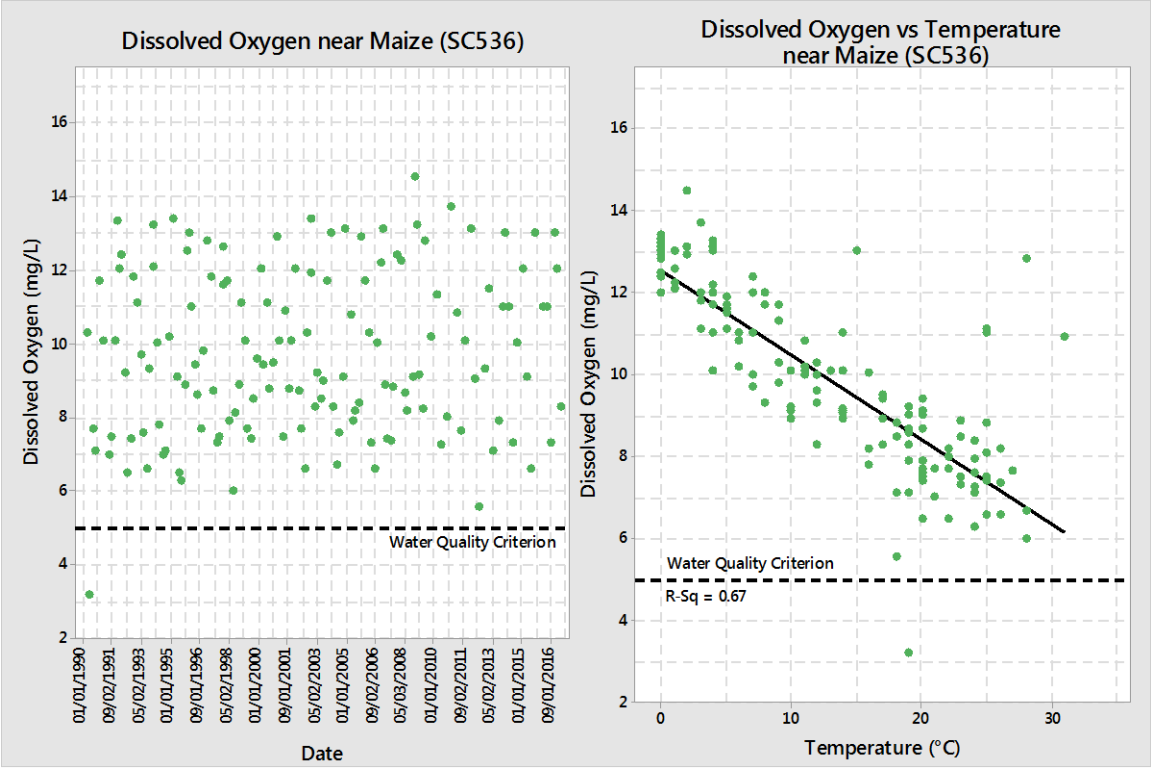


Figure 41. Dissolved oxygen and the relationship between dissolved oxygen and temperature at Wichita (SC758) in the Arkansas River, March 23, 2010 to April 18, 2017.

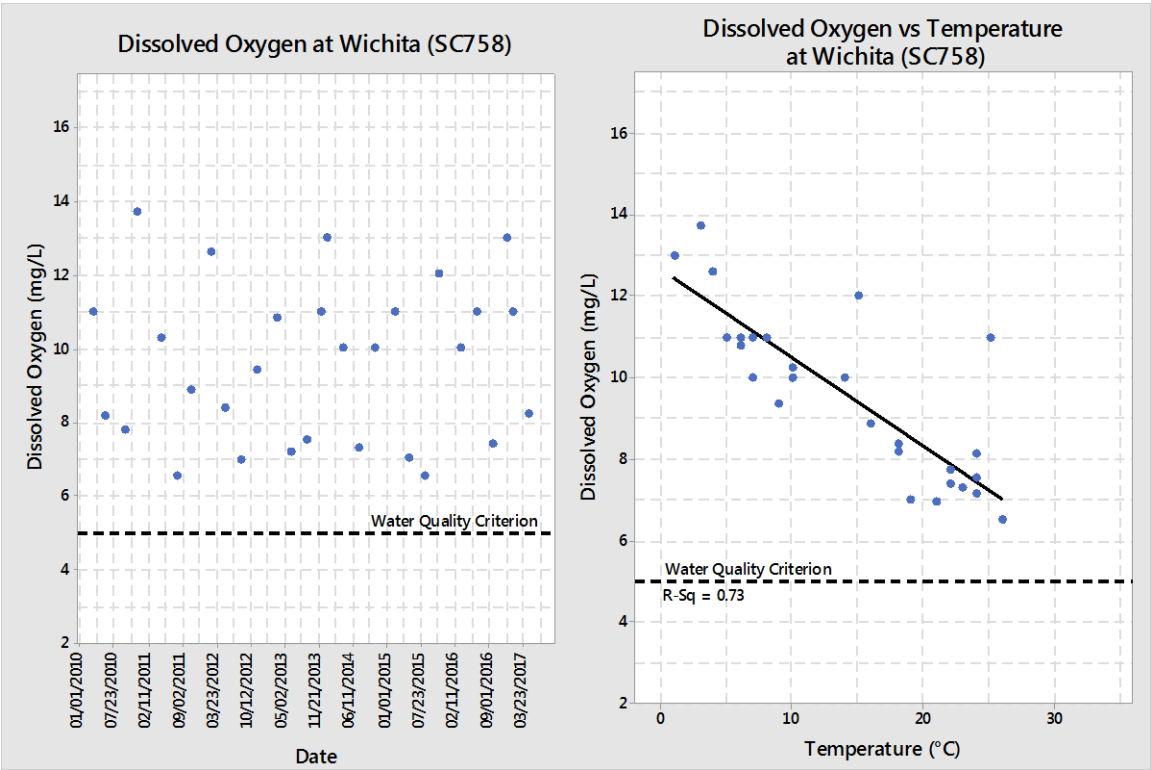


Table 8. Mean dissolved oxygen, dissolved oxygen saturation, and temperature, as well as median pH, by season (spring: April through June; summer-fall: July through October, winter: November through March) in the Arkansas River, March 19, 1990 to April 18, 2017.

Station	Spring	Summer-Fall	Winter	All Seasons
Dissolved Oxygen (mg/L)				
Hutchinson (SC523)	9.42	9.24	11.70	10.32
Yoder (SC524)	9.32	9.67	11.59	10.39
Maize (SC536)	8.49	8.16	11.67	9.71
Wichita (SC758)	8.77	7.64	11.54	9.56
Dissolved Oxygen Saturation (%)				
Hutchinson (SC523)	103	108	99.7	103
Yoder (SC524)	105	116	102	108
Maize (SC536)	86.9	91.0	91.4	90.1
Wichita (SC758)	92.2	85.0	93.6	90.6
pH				
Hutchinson (SC523)	8.2	8.2	8.1	8.2
Yoder (SC524)	8.2	8.3	8.2	8.2
Maize (SC536)	8.2	8.1	8.1	8.1
Wichita (SC758)	8.0	7.8	7.9	7.9
Temperature (°C)				
Hutchinson (SC523)	20.56	23.23	8.61	16.37
Yoder (SC524)	21.46	24.66	10.10	17.72
Maize (SC536)	18.00	20.96	5.32	13.68
Wichita (SC758)	18.13	21.11	6.58	14.28

Primary productivity increases in the spring and summer-fall, when temperatures increase and DO concentrations decrease. When primary productivity is excessive, oxygen from photosynthesis can create DO concentrations that exceed the natural oxygen equilibrium of the water at a given temperature, and the water is considered supersaturated. All stations along the Arkansas River display supersaturated conditions exceeding 110% DO saturation throughout the period of record. The stations with the most frequent excursions greater than 110% DO saturation are Hutchinson (SC523) and Yoder (SC524; **Figures 42-45**). The stations with the fewest excursions above 110% are Maize (SC536) and Wichita (SC758; **Figures 44-45**). The station with the most frequent high DO saturation is Yoder (SC524). This station has the highest overall mean DO saturation (108%), as well as the highest seasonal mean in the summer-fall (116%).

Figure 42. Dissolved oxygen saturation and the relationship between dissolved oxygen saturation and temperature near Hutchinson (SC523) in the Arkansas River, March 19, 1990 to April 17, 2017.

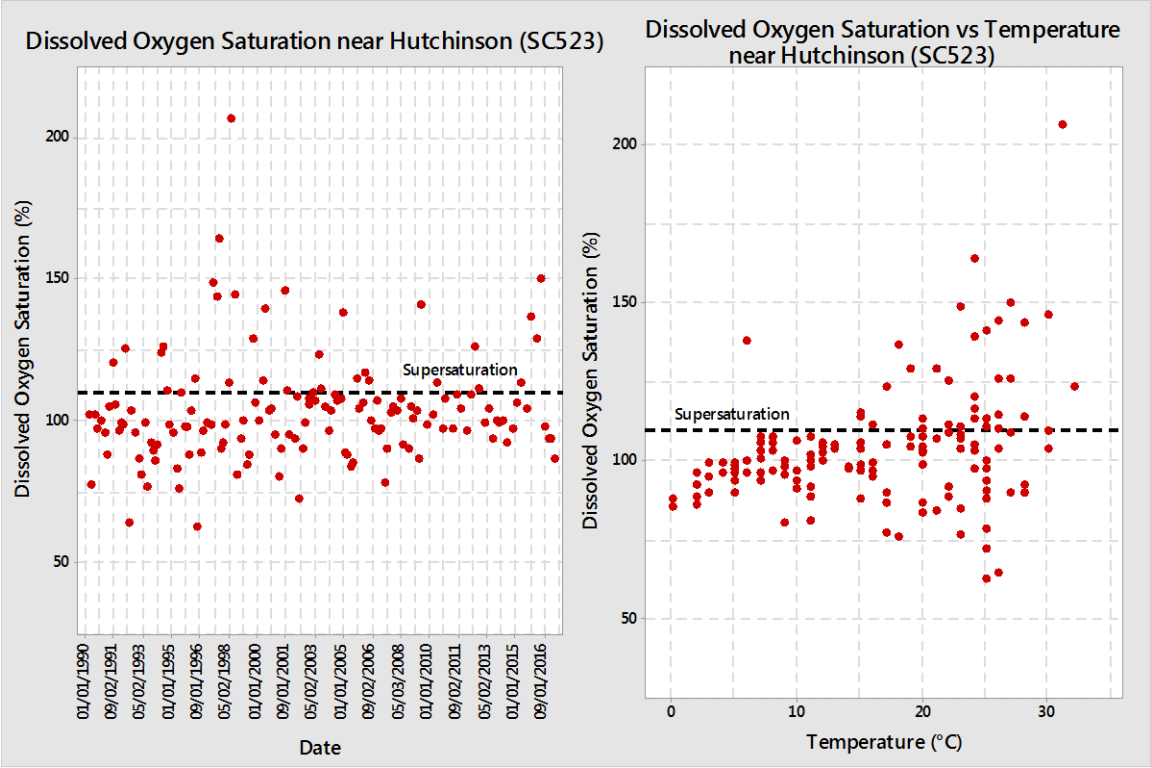


Figure 43. Dissolved oxygen saturation and the relationship between dissolved oxygen saturation and temperature near Yoder (SC524) in the Arkansas River, March 19, 1990 to April 17, 2017.

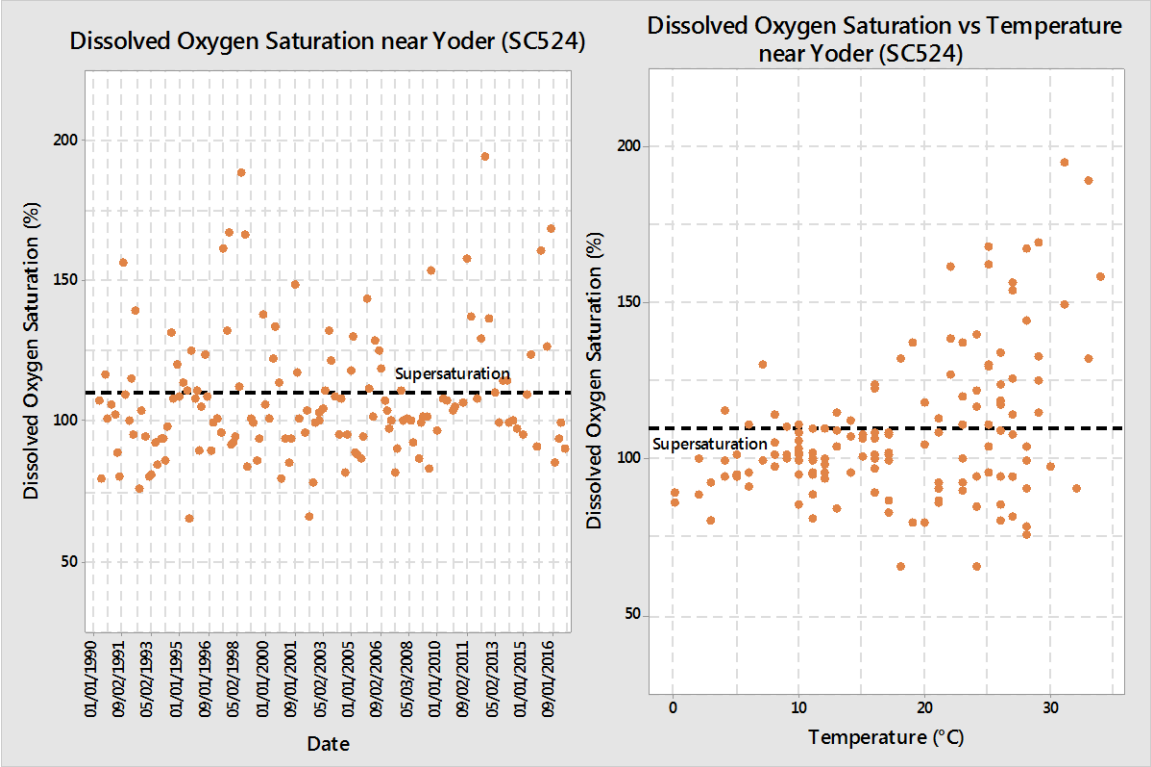


Figure 44. Dissolved oxygen saturation and the relationship between dissolved oxygen saturation and temperature near Maize (SC536) in the Arkansas River, March 21, 1990 to April 18, 2017.

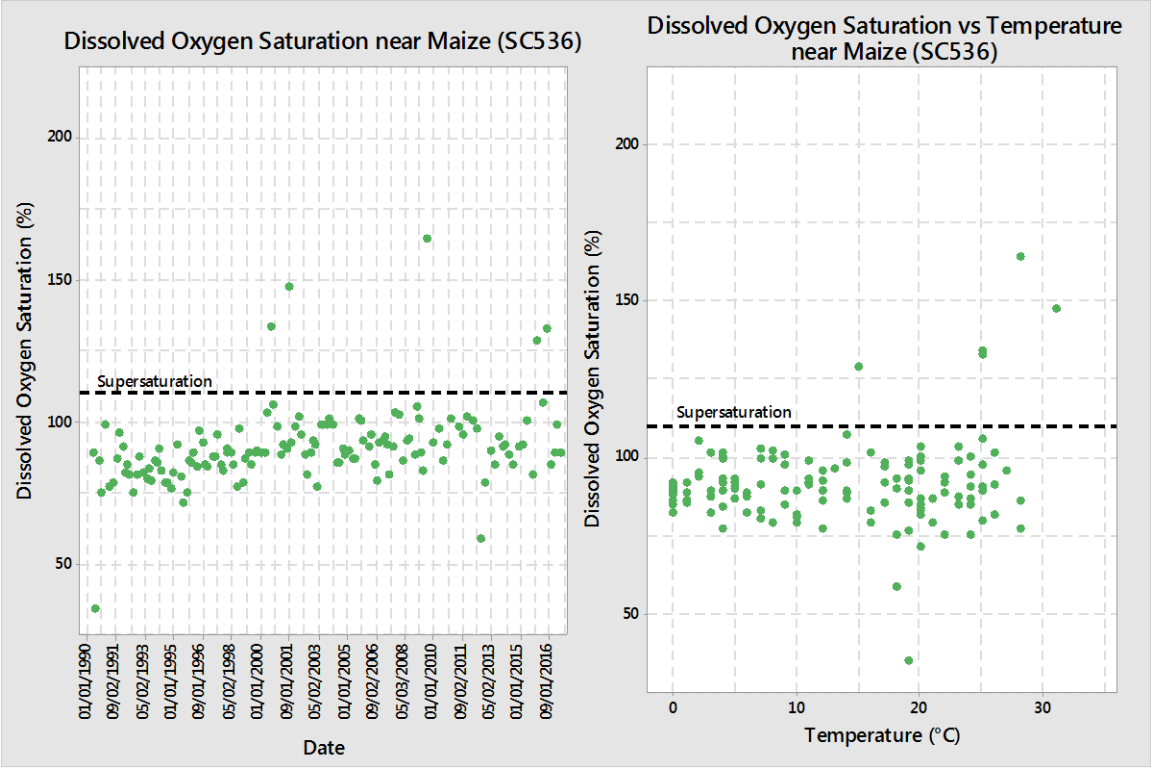
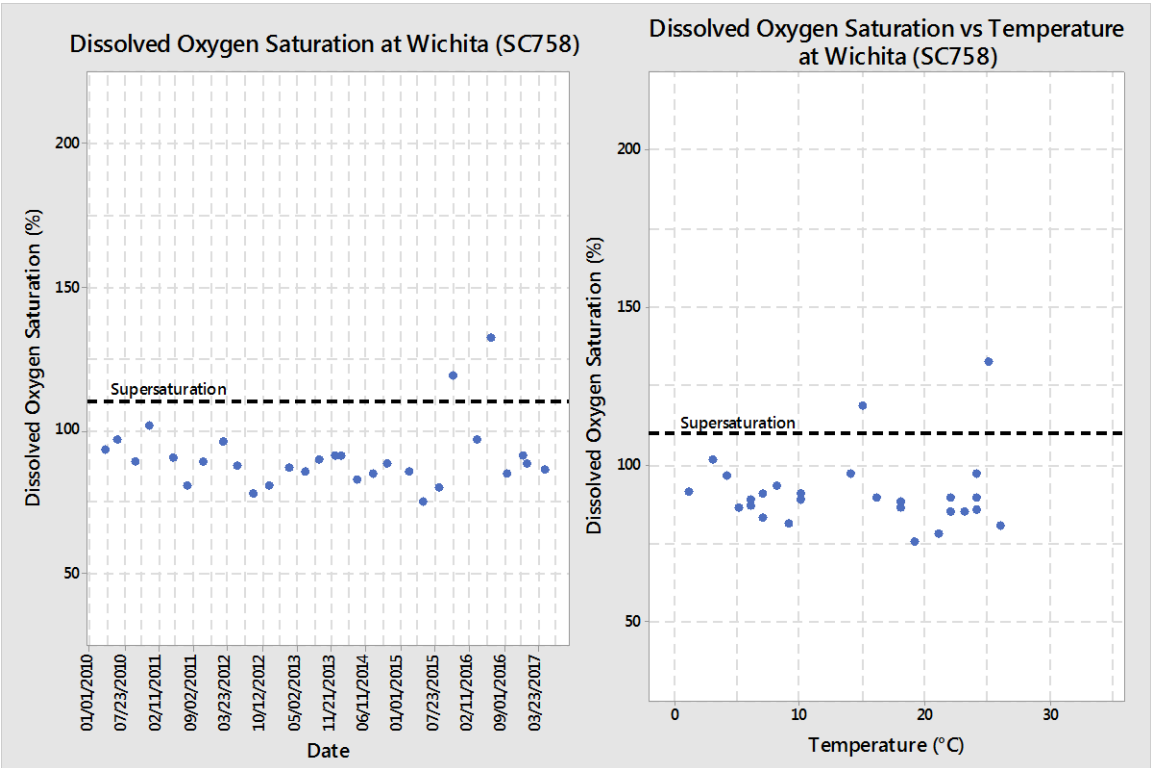


Figure 45. Dissolved oxygen saturation and the relationship between dissolved oxygen saturation and temperature at Wichita (SC758) in the Arkansas River, March 23, 2010 to April 18, 2017.



Another water quality indicator of primary productivity is pH, as photosynthesis can increase pH by removing carbon dioxide from the water. Elevated pH typically occurs as temperatures increase (**Figures 46-49**). The numeric water quality criteria for pH is a range from 6.5 to 8.5. The stations with the most frequent excursions above 8.5 are Hutchinson (SC523) and Yoder (SC524; **Figures 46-47**). There have been no excursions near Hutchinson (SC523) since 2004 and two excursions near Yoder (SC524) from 2004 to 2017. The majority of all excursions near Yoder (SC524) occurred prior to 2004 and typically coincided with pH excursions near Hutchinson (SC523). There are few pH excursions near Maize (SC536), and there has never been an excursion at Wichita (SC758; **Figures 48-49**). Median pH remains relatively consistent throughout all the seasons, ranging from 7.8 to 8.3.

Figure 46. The pH and the relationship between pH and temperature near Hutchinson (SC523) in the Arkansas River, March 19, 1990 to April 17, 2017.

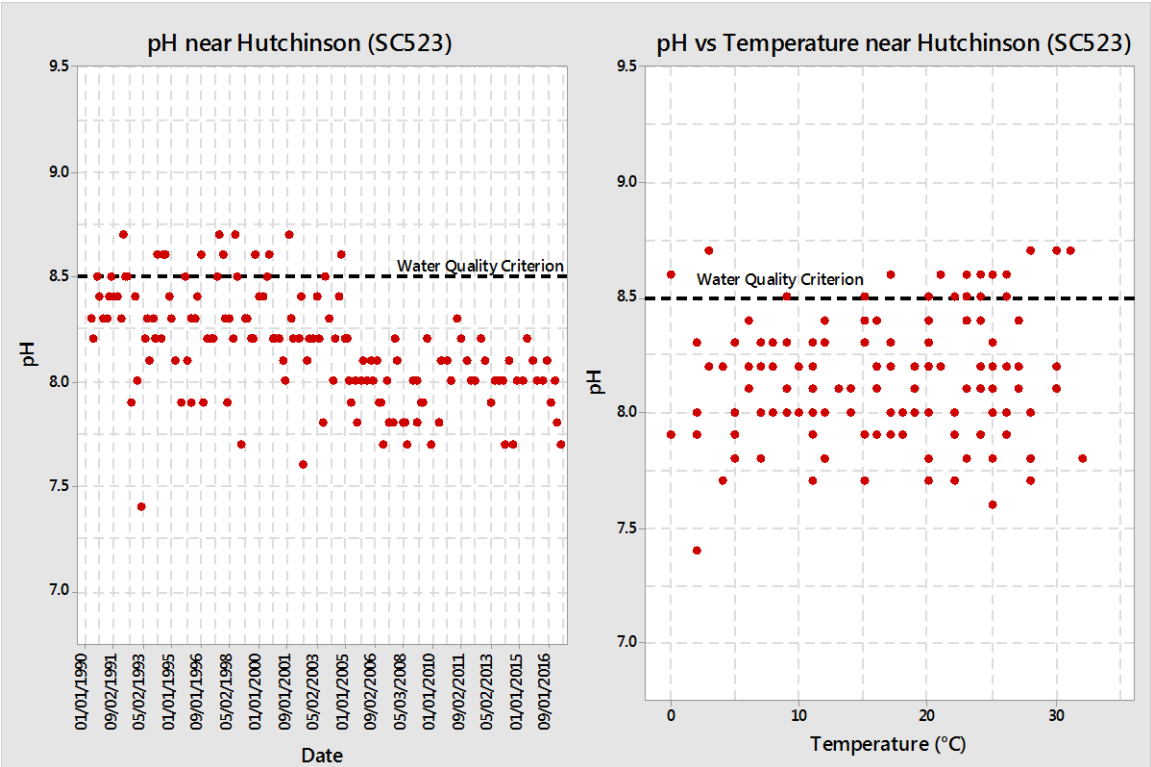


Figure 47. The pH and the relationship between pH and temperature near Yoder (SC524) in the Arkansas River, March 19, 1990 to April 17, 2017.

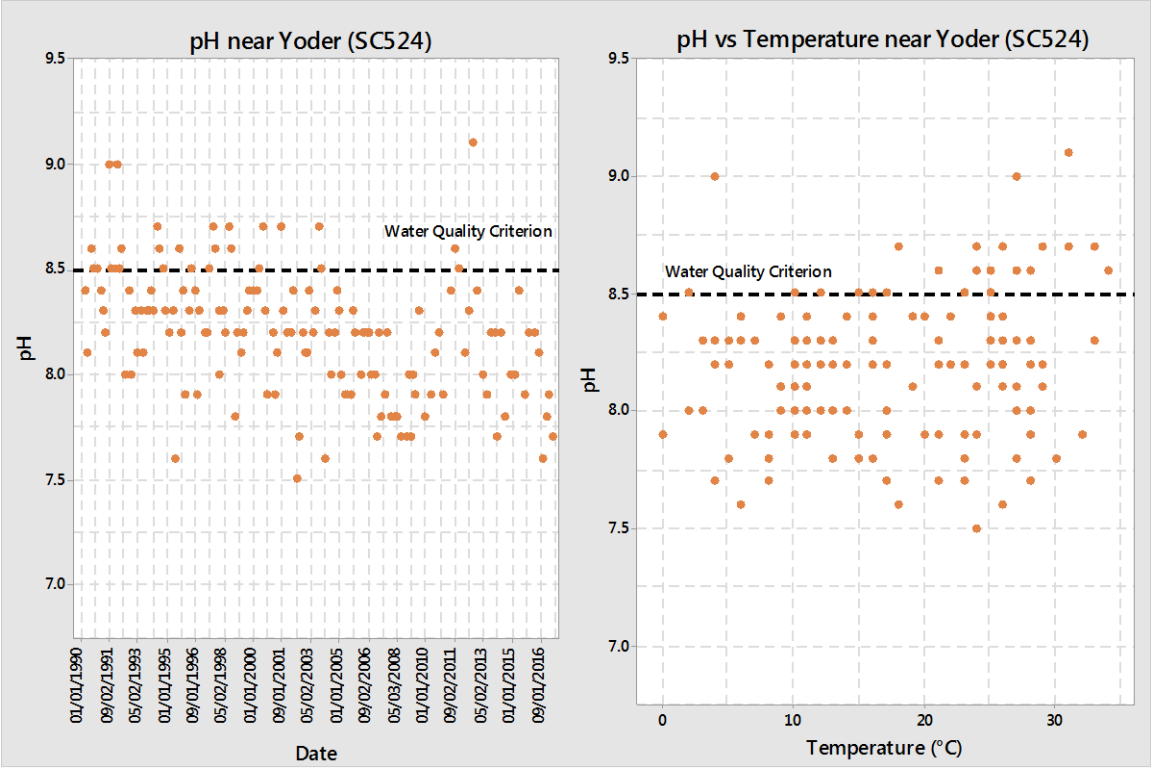


Figure 48. The pH and the relationship between pH and temperature near Maize (SC536) in the Arkansas River, March 21, 1990 to April 18, 2017.

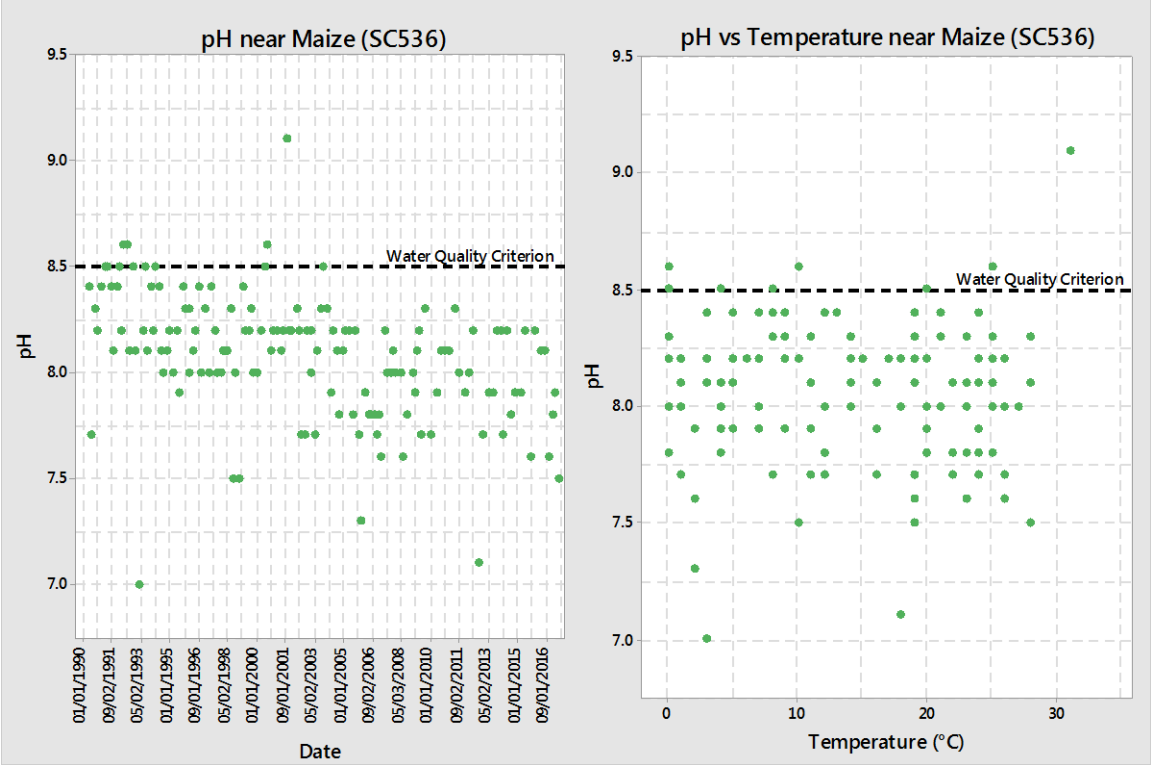
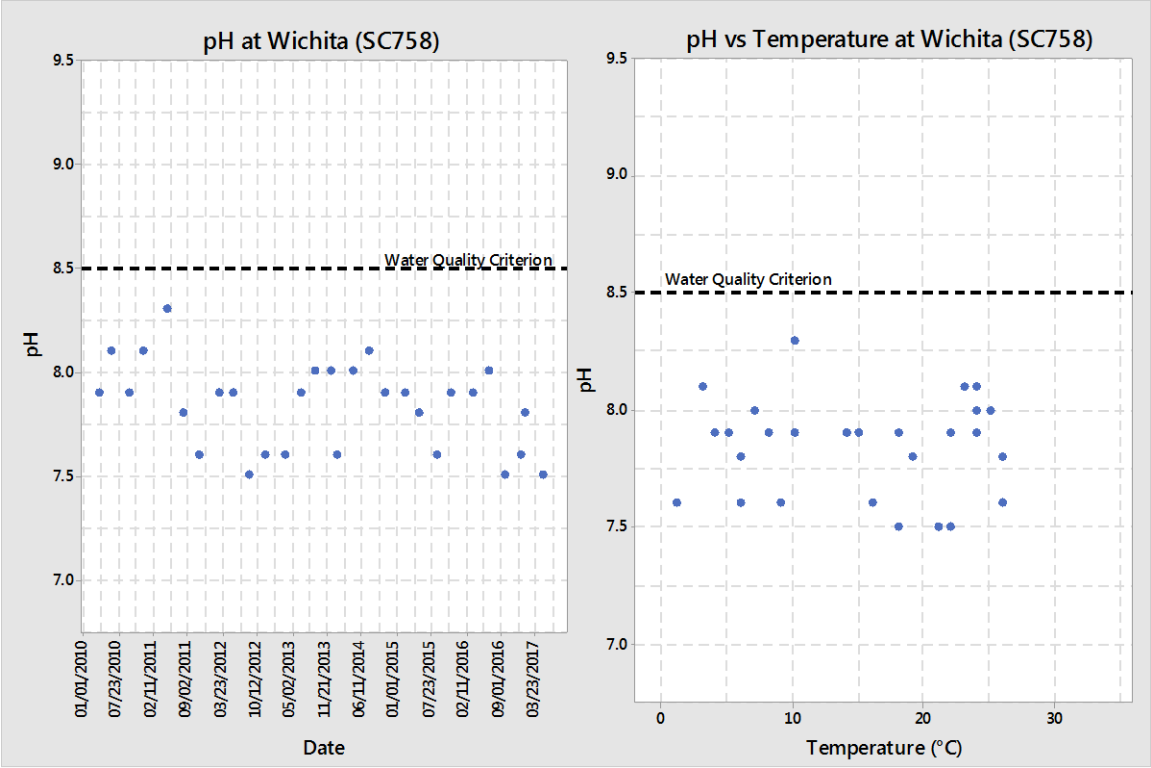


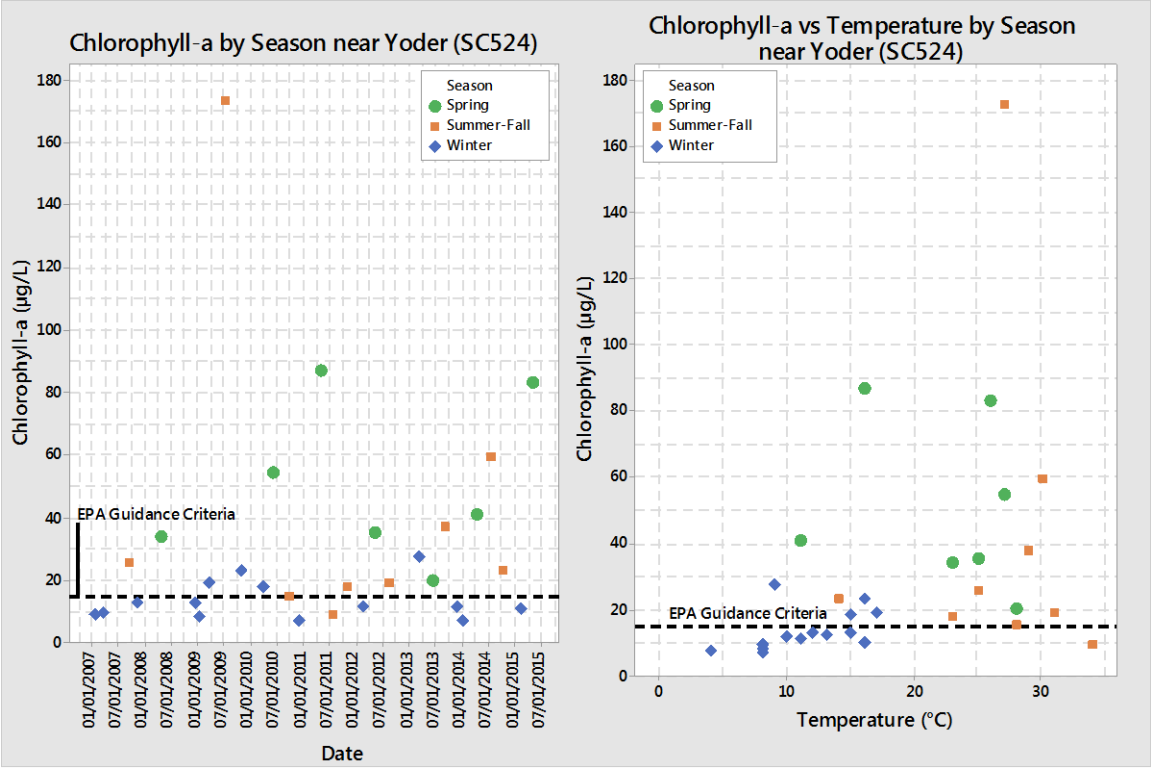
Figure 49. The pH and the relationship between pH and temperature at Wichita (SC758) in the Arkansas River, March 23, 2010 to April 18, 2017.



Chlorophyll-*a* is a photosynthetic pigment found in algae, and its concentration is commonly used as a measure of the algal biomass present in streams. Chlorophyll-*a* data is collected by KDHE near Yoder (SC524). Interpretation of chlorophyll-*a* data must be qualified by the following: sample station is heavily influenced by municipal WWTP effluent and therefore may not be representative of other stations; samples collected form a comparatively small sample set in relation to other parameters; and sample collection is based upon visual confirmation of the presence of algae, creating a bias towards high chlorophyll-*a* concentrations in the data set. Because of these factors, available chlorophyll-a data must be interpreted with caution.

Data is available from 2007 to 2015 (**Figure 50**), and concentrations near Yoder (SC524) range from 6.9 to 173 µg/L with a mean of 30.6 µg/L and a median of 18.9 µg/L. Because nutrients directly influence primary production, the U.S. Environmental Protection Agency (USEPA) guidance on nutrient criteria for streams establishes a chlorophyll-*a* concentration range of 8-15 µg/L before overall biology can become adversely impacted (U.S. Environmental Protection Agency, 2000). This criteria is frequently exceeded during the spring and summer-fall near Yoder (SC524; **Figure 50**).

Figure 50. Chlorophyll-*a* and the relationship between chlorophyll-*a* and temperature by season near Yoder (SC524) in the Arkansas River, January 23, 2007 to May 4, 2015.



During the spring and summer-fall, chlorophyll-*a* concentrations increase as temperatures increase (**Figure 50**). Typically, higher chlorophyll-*a* concentrations occur at lower DO concentrations (7-11 mg/L) in the spring and summer-fall, which is an expected trend for seasons with warmer temperatures (**Figure 51**). Supersaturated conditions for DO saturation (**Figure 51**) and elevated pH values (**Figure 52**) occur in the spring and summer-fall and can coincide with higher chlorophyll-*a* concentrations. Chlorophyll-*a* concentrations vary across the range of TP concentrations revealing that additional factors, such as season, are integral to driving TP uptake by primary producers (**Figure 52**); for example, concentrations of 0.1 to 0.2 mg/L TP can elicit double to triple the chlorophyll-*a* concentrations in spring compared to the same TP concentrations in winter.

Understanding the activity of primary producers and their interaction with and affect upon water quality is imperitive to interpreting the biological health of a stream. Specifically, and as previously mentioned, primary productivity can alter ambient levels of oxygen and the acid-base balance in the stream through photosynthesis and respiration, resulting in shifts in the biological community within the stream.

Figure 51. Relationship between chlorophyll-*a* and dissolved oxygen and dissolved oxygen saturation by season near Yoder (SC524) in the Arkansas River, January 23, 2007 to May 4, 2015.

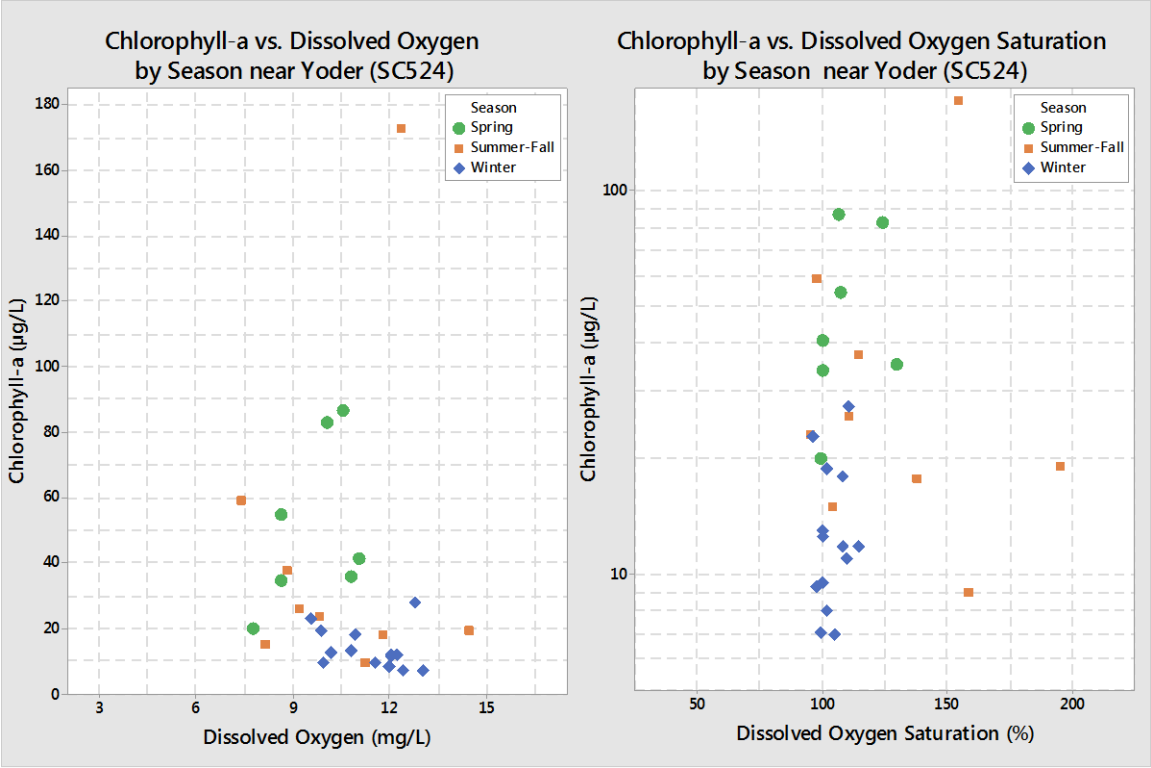
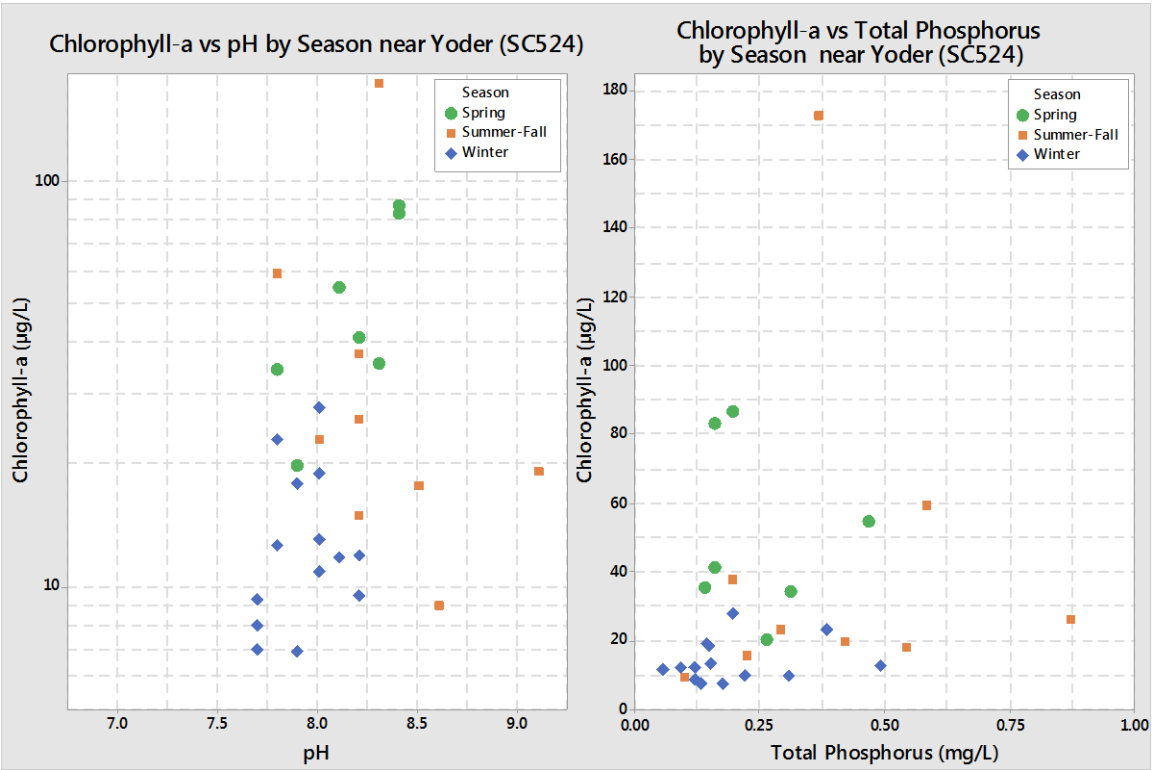


Figure 52. Relationship between chlorophyll-*a* and pH and total phosphorus by season near Yoder (SC524) in the Arkansas River, January 23, 2007 to May 4, 2015.



KDHE's Stream Biological Monitoring Program has one main stem station on the Arkansas River between Hutchinson and Wichita that has been assessed using the Aquatic Life Use Support Index (ALUS) Index as described in Kansas' 2018 303(d) Methodology. The ALUS Index consists of five categorizations of biotic condition that, once measured, are assigned a score (**Table 9**). Scores are then tallied and a support category is assigned according to **Table 10**.

1. Macroinvertebrate Biotic Index (MBI): A statistical measure that evaluates the effects of nutrients and oxygen demanding substances on macroinvertebrates based on the relative abundance of certain indicator taxa (orders and families).
2. Ephemeroptera, Plecoptera, and Trichoptera (EPT) abundance as a percentage of the total abundance of macroinvertebrates.
3. Kansas Biotic Index for Nutrients (KBI-N): Mathematically equivalent to the MBI, however, the tolerance values are species specific and restricted to aquatic insect orders.
4. EPT Percent of Count (EPT % CNT) – The percentage of organisms in a sample consisting of individuals belonging to the EPT orders.
5. Shannon's Evenness (SHN EVN) – A measure of diversity that describes how evenly distributed the numbers of individuals are among the taxa in a sample.

Table 9. Aquatic Life Use Support Index (ALUS) Index metrics with scoring ranges.

MBI	KBI-N	EPT	EPT % CNT	SHN EVN	Score
<= 4.18	<= 2.52	>= 16	>= 65	>= 0.849	4
4.19-4.38	2.53-2.64	14-15	56-64	0.826-0.848	3
4.39-4.57	2.65-2.75	12-13	48-55	0.802-0.825	2
4.58-4.88	2.76-2.87	10-11	38-47	0.767-0.801	1
>= 4.89	>= 2.88	<= 9	<= 37	<= 0.766	0

Table 10. Aquatic Life Use Support Index (ALUS) Index score range, interpretation of biotic condition, and support category.

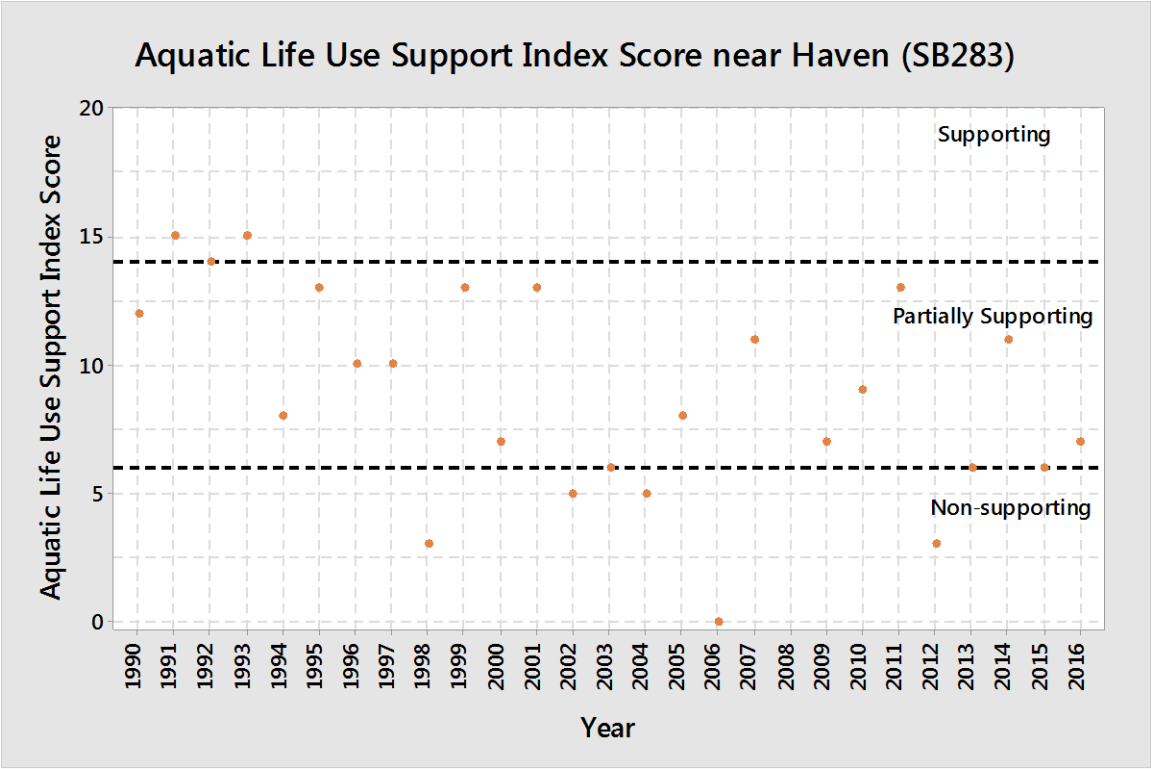
ALUS Index Score	Biotic Condition	Support Category
>16-20	Very Good	Supporting
>13-16	Good	
>7-13	Fair	Partially Supporting
>4-6	Poor	Non-supporting
0-3	Very Poor	

The SB station in the TMDL watershed, Arkansas River near Haven (SB283), is located downstream of Yoder (SC524). The station near Haven (SB283) has been assessed using the ALUS Index with annual samples (except for 2008) from 1990 to 2016, with a total of 26 samples. The mean ALUS Index score indicates biotic conditions are fair, and the station is classified as partially supporting aquatic life (**Table 11**). In general, biotic conditions have declined from 1990 to 2016 (**Figure 53**). Mean ALUS Index scores prior to 2001 are approximately 11, while mean ALUS Index scores post 2001 are approximately 7.

Table 11. Mean Aquatic Life Use Support (ALUS) Index scores near Haven (SB283) in the Arkansas River.

Station	Period of Record	Number of Samples	Mean ALUS Index Score	Biotic Condition	ALUS Index Support Category
Haven (SB283)	Oct. 3, 1990 to Oct. 13, 2016	26	9	Fair	Partially Supporting

Figure 53. Aquatic Life Use Support Index scores near Haven (SB283) in the Arkansas River, October 3, 1990 to October 13, 2016.



Desired Endpoints of Water Quality (Implied Load Capacity) in the Arkansas River from Hutchinson to Wichita.

The ultimate endpoint of this TMDL will be to achieve the Kansas Water Quality Standards by eliminating the impacts to aquatic life, domestic water supply, and recreation associated with excessive phosphorus and objectionable flora as described in the narrative criteria pertaining to nutrients. There are no existing numeric phosphorus criteria currently in Kansas. The U.S. EPA suggested benchmark for stream TP in the South Central Cultivated Great Plains Nutrient Ecoregion V is 0.067 mg/L over the ten-state aggregate of Level III ecoregions.

The Arkansas River Watershed included in this document lies within the U.S. EPA Level III Ecoregion of the Central Great Plains (27). Assessment of TP data from the 129 KDHE monitoring stations located in the Central Great Plains ecoregion for the 2000 through April 2018 period of record was used to establish TP management milestones for the TMDLs included in this document (**Table 12**).

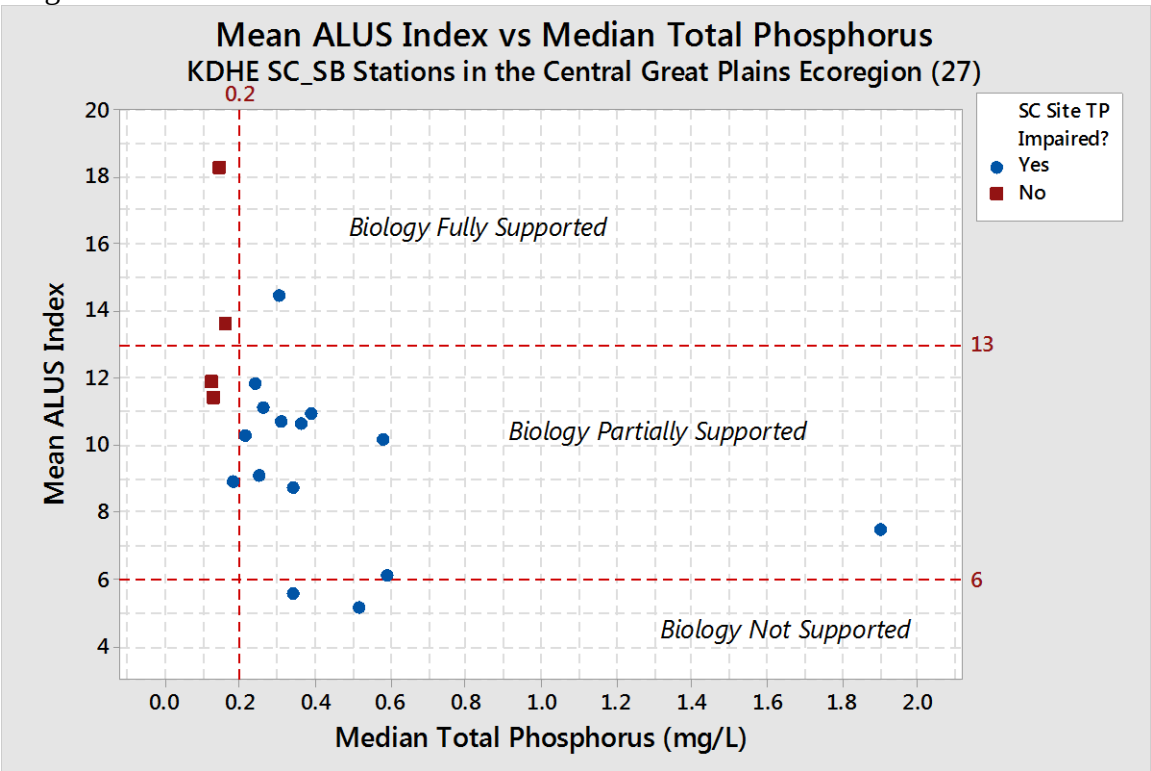
Table 12. Summary data of Kansas Department of Health and Environment (KDHE) stream chemistry stations located in US EPA Level III Ecoregion of the Central Great Plains (27) for the 2000 through April 2018 period of record.

US EPA Level III Ecoregion	Number of KDHE Stations	Number of Samples	Q1 of Station Medians (mg/L)	Median of Station Medians (mg/L)	Q3 of Station Medians (mg/L)
Central Great Plains (27)	129	7,248	0.130	0.200	0.374

Current EPA nutrient philosophy is predicated on the lowest quartile of stream total phosphorus within an ecoregion as indicative of minimal impact conditions. This generalization is not tied to specific biological conditions but represents water quality protection policy guiding EPA's administration of clean water programs.

Figure 54 displays the relationship between median phosphorus values and ALUS Index score within the Central Great Plains (27) Ecoregion. Higher ALUS Index scores are indicative of higher quality biological communities. There are 19 KDHE monitoring stations located in the Central Great Plains Ecoregion that have corresponding biology and TP datasets over the 1990 through 2016 period of record. When median TP concentrations are compared to the mean ALUS Index for those stations, the resulting plot reveals three stations fully supporting biology with median TP values ranging from 0.140 to 0.300 mg/L while stations partially supporting biology have TP concentrations ranging from to 0.180 to 1.90 mg/L. The three stations in the ecoregion currently unimpaired for TP have a mean ALUS Index of 15.4; meanwhile, the impaired stations on the 303(d) list for TP demonstrate less support for biology with a mean ALUS Index of 9.4.

Figure 54. Median total phosphorus (TP) versus mean Aquatic Life Use Score (ALUS) Index for stream chemistry/stream biology (SC/SB) stations located in Kansas' Central Great Plain Ecoregion (27) from 1990 through 2016.



The greatest complication in setting an endpoint is establishing the linkage of phosphorus levels to applicable biologic response variables. Displayed in **Figure 54** is a noisy relationship between the ALUS Index and phosphorus that defies establishing a solitary threshold value and supports an adaptive management approach to reduce current phosphorus loads and concentrations; this adaptive management approach requires observing and responding to improvement in biological metrics and sestonic chlorophyll-*a* prior to further reductions. Therefore, the primary measure of reduction in nutrient loading to the impaired segments in the TMDL watershed will be the ALUS Index. The ALUS Index will serve to establish if the biological community at the SC stations in the watershed reflect recovered, renewed diversity and minimal disruption by the impacts described in the narrative criteria for nutrients on aquatic life, recreation, and domestic water supply.

Additionally, the concentration of suspended sestonic phytoplankton in the water column at KDHE SC stations will indicate if primary productivity has moderated to reduce the impacts described in the narrative criteria for nutrients on aquatic life, recreation, and domestic water supply.

Secondary indicators of the health of the instream biological community include:

1. Dissolved oxygen concentrations greater than 5.0 mg/L and the dissolved oxygen saturation not more than 110%. Dissolved oxygen saturation is the measure of oxygen in the water relative to the water's potential dissolved oxygen concentration. Dissolved oxygen concentrations below 5.0 mg/L put aquatic life under stress while dissolved oxygen saturation percentages greater than 110% are indicative of over-active primary productivity.

2. Instream pH values remain below 8.5. Excessive nutrients can induce vigorous photosynthesis which will cause pH to rise above 8.5, the current Kansas water quality criterion.

Therefore, the numeric endpoints for segments included in this TMDL, as measured at Yoder (SC524), Maize (SC536), Wichita (SC758), and Haven (SB283), indicating attainment of water quality standards within the watershed are:

1. An ALUS Index score greater than 13 at SB stations.
2. Median sestonic chlorophyll-*a* concentrations less than or equal to 10 µg/L at SC stations.
3. Dissolved oxygen concentrations greater than 5.0 mg/L at SC stations.
4. Dissolved oxygen saturation less than 110% at SC stations.
5. Values within the range of 6.5 to 8.5 for pH at SC stations.

All five endpoints must be initially maintained over three consecutive years to constitute full support of the designated uses of the impaired stream segments included in the TMDL watershed as measured at Yoder (SC524), Maize (SC536), Wichita (SC758), and Haven (SB283). After the endpoints are attained, simultaneous digression of these endpoints more than once every three years, on average, constitutes a resumption of the TP impairment at the respective station unless the TP impairment is delisted through the 303(d) process.

There are no existing numeric phosphorus criteria currently in Kansas. Hence, the endpoint established by this TMDL will be the measure used to indicate full support of aquatic life, domestic water supply, and recreation uses in the river. These endpoints will be evaluated periodically as phosphorus levels decline in the watershed over time, with achievement of the ALUS Index endpoint indicating the restored status of the aquatic life use in the river.

This TMDL looks to establish a protective TP endpoint for the unimpaired segments in the Hutchinson (SC523) Watershed by using the stream chemistry station's 2000 through 2016 median TP concentration of 0.096 mg/L; this TP concentration is protective of the current conditions and attained uses as they relate to nutrient loading. Additionally, this TMDL will establish phased TP milestones, derived from the central tendency of concentrations within the Kansas Central Great Plains Ecoregion, for Arkansas River segments included in the Yoder (SC524), Maize (SC536), and Wichita (SC758) watersheds (**Table 13**). These milestones will cue the examination for altered, improved biological conditions in the river. Once TP concentrations at the KDHE SC station at Yoder (SC524) approaches the Phase I management milestone of 0.200 mg/L, assessment of the biological community in the river will be initiated at the KDHE SB station near Haven (SB283). Should the biological community fail to respond to the Phase I reduction of TP, Phase II will commence. Simultaneous achievement of the chlorophyll-*a*, dissolved oxygen, dissolved oxygen saturation, and pH endpoints will signal phosphorus reductions are addressing the accelerated succession of aquatic biota and the development of objectionable concentrations of algae and algae by-products, thereby restoring the domestic water supply and contact recreation uses in the river.

Table 13. Total phosphorus (TP) current condition (2000 through April 2017) and Phase I and Phase II TP milestones for the Arkansas River Watershed from Hutchinson to Wichita.

Stream Chemistry Station	Current Condition	TMDL Phase I		TMDL Phase II	
	Median TP (mg/)	TP Milestone (mg/L)	Reduction in TP from Current Concentration	TP Milestone (mg/L)	Reduction in TP from Current Concentration
Arkansas R near Hutchinson (SC523)	0.096	0.096	Protected at 0.096 mg/L	0.096	Protected at 0.096 mg/L
Arkansas R near Yoder (SC524)	0.212	0.200	6%	0.130	40%
Arkansas R near Maize (SC536)	0.192	0.192	Protected at 0.192 mg/L	0.130	33%
Arkansas R near Wichita (SC758)	0.125	0.125	Protected at 0.125 mg/L	0.125	Protected at 0.125 mg/L

3. SOURCE INVENTORY AND ASSESSMENT

Point Sources: The Arkansas River Watershed from Hutchinson to Wichita, comprising the SC523, SC524, SC536, and SC758 watersheds, has 19 NPDES permitted facilities (**Table 14**). Of these, there are two municipal mechanical facilities, three discharging lagoon facilities, and four non-discharging lagoon facilities that are prohibited from discharging. It also comprises one groundwater remediation site, one drinking water plant, and three industrial facilities that utilize non-contact cooling water. There is only one permitted facility in the SC523 watershed, and there are two permitted facilities in the SC758 watershed. The SC524 and SC536 watersheds consist of six facilities each. Discharge Monitoring Report (DMR) data for a period of record from 2008 to 2017 is used to assess the current effluent flow and current mean total phosphorus (TP) in the effluent.

The Hutchinson WWTP in the SC524 watershed utilizes anaerobic sludge digestion with a designed discharge rate of 8.3 MGD. Mean TP from the weekly-monitored effluent data is 0.33 mg/L. Similarly, the City of South Hutchinson, also in the SC524 watershed, utilizes activated sludge for wastewater treatment and performs TP monitoring twice each month. It has the highest mean TP discharge of 7.46 mg/L from the monitored effluent data. Reno Co. S.D. #202 in the SC536 watershed has a three-cell discharging lagoon with a design flow of 0.02 MGD. It is monitored annually for TP. Since 2008, current flow has only been measured thrice (all in May 2008). Three dipped samples of TP were measured in 2016 when discharge from this facility was reported. The wastewater treatment facilities in the City of Nickerson (design flow of 0.18 MGD) and the City of Haven (design flow of 0.25 MGD) utilize three- and four-cell lagoon wastewater stabilization systems, respectively, and discharge to the Arkansas River. Although both of these facilities are not required to monitor TP, they will be assigned a wasteload allocation as they are discharging facilities. A study on lagoon wastewater quality by KDHE indicated that an average of 2 mg/L of phosphorus is typical for lagoon effluent. All discharging facilities are assigned a wasteload allocation in Section 4.

Whispering Pines Trailer Court (one-cell), the City of Bentley (three-cell), the City of Mount Hope (five-cell), and Reno Co. S.D. #201 (three-cell) utilize wastewater stabilization lagoon systems that are

prohibited from discharging; hence, they are assigned wasteload allocations of zero. The City of Bentley's wastewater treatment facility is, however, an exceptional case. Although there is TP data due to their requirement to monitor monthly when irrigating, they will nevertheless be assigned a zero TP wasteload allocation because it is a non-discharging facility. A current flow of irrigation water of 0.12 MGD is reported.

FI Kansas Remediation Trust Site is a groundwater remediation site designed to discharge about 0.22 MGD. It is required to monitor TP annually. With no TP sampled, a nominal wasteload allocation is given to this permit in section 4. Wichita Water Treatment Plant is a public water treatment plant with a discharge of 0.72 MGD but is not required to monitor for TP. It is a public water treatment plant and is permitted for the temporary discharge of non-chlorinated filter influent water, filter backwash water, and miscellaneous waters from on-line monitoring equipment. The untreated waters are then routed to the Arkansas River via a storm sewer. Morton Salt, Inc., Sonoco Hutchinson Mill, LLC, and Marina Point Office Park, LLC discharge non-contact cooling water, which is not subjected to any treatment. Hence, these facilities will be assigned a nominal wasteload allocation in section 4.

Table 14. NPDES facilities in the Arkansas River Watershed from Hutchinson to Wichita. Data is qualified with the following: * - no data available; ** - not required to monitor TP as condition of current NPDES permit; n/a - not applicable; $^{+}$ - updated permit in process.

Site	Permit #	Permitee	Type	Current Effluent Flow (MGD)	Current Avg. TP (mg/L) in Effluent	TP Monitoring Frequency	Permit Expires	Receiving Stream
SC523	M-AR02-OO01	City of Alden	Municipal 3 Cell Discharging Lagoon	**	1.73	Quarterly	9/30/22	Arkansas R
SC523	M-AR66-OO02	City of Nickerson	Municipal 3 Cell Discharging Lagoon	0.055	*	**	3/31/23	Arkansas R
SC523	M-AR49-OO01	Fun Valley Wastewater Treatment Lagoons	Municipal 2 Cell Discharging Lagoon	*	*	Quarterly	3/31/22	Arkansas R
SC523	I-AR66-PR01	Gravel & Concrete, Inc.	Concrete Plant	*	*	**	9/30/22	Arkansas R
SC524	M-AR49-IO01	City of Hutchinson	Municipal Mechanical Activated Sludge	4.76	0.33	Weekly	12/31/18	Arkansas R via ¼ mile Ditch
SC524	M-AR82-OO02	City of South Hutchinson	Municipal Mechanical Activated Sludge	0.69	7.46	Twice monthly	11/30/22	Arkansas R via Unnamed Tributary
SC524	I-AR82-PO15	Former Farmland Industries – South Hutchinson	Groundwater Remediation Air Stripper	0.12	*	Annually	12/31/18	Arkansas R

Site	Permit #	Permitee	Type	Current Effluent Flow (MGD)	Current Avg. TP (mg/L) in Effluent	TP Monitoring Frequency	Permit Expires	Receiving Stream
SC524	I-AR82-PO01	Morton International	Non-contact Cooling Water & Stormwater	2.63	*	**	3/31/14+	Arkansas R
SC524	I-AR82-PR01	Mid America Redi Mix	Concrete Plant	*	*	**	9/30/22	Arkansas R
SC524	C-AR82-NO02	Whispering Pines Trailer Court	Non Discharging 1 Cell Lagoon	n/a	n/a	n/a	10/31/18	n/a
SC536	M-AR41-OO01	City of Haven	Municipal 4 Cell Discharging Lagoon	*	*	**	10/31/22	Arkansas R via Gar Cr
SC536	I-AR98-PO01	Reno Co. S.D. #202	Municipal 3 Cell Discharging Lagoon	0.03	2.34	Annually	12/31/18	Arkansas R via Unnamed Tributary
SC536	M-AR11-NO01	City of Bentley	Non Discharging 3 Cell Municipal Lagoon	n/a	n/a	n/a	10/31/18	n/a
SC536	M-AR62-NO01	City of Mount Hope	Non Discharging 5 Cell Municipal Lagoon	n/a	n/a	n/a	7/31/18	n/a
SC536	M-AR49-NO07	Reno Co. S.D. #201	Non Discharging 5 Cell Municipal Lagoon	n/a	n/a	n/a	12/31/19	n/a
SC536	I-AR49-CO04	Sonoco Hutchinson Mill, LLC	Non-contact Cooling Water	*	*	**	11/30/18	Arkansas R via Grand View Drainage Ditch
SC536	I-AR49-PR01	Concrete Enterprises, Inc.	Concrete Plant	*	*	**	9/30/22	Arkansas R via Storm Sewer
SC758	I-AR94-PO10	Wichita, Water Treatment Plant	Drinking Water Plant	*	*	**	6/30/22	Arkansas R via Storm Sewer
SC758	I-AR94-CO63	Marina Point Office Park, LLC	Non-contact Cooling Water & Stormwater	0.16	*	**	11/30/22	Arkansas R via Storm Sewer

There are 11 permitted facilities that are currently discharging to the Arkansas River Watershed from Hutchinson to Wichita, but only six facilities, including the Municipal Separate Storm Sewer (MS4), are required to monitor for TP in their effluent as part of their NPDES permit. **Table 15** shows the facilities that currently discharge more than 10 lbs/day of TP in their effluent. South Hutchinson WWTP is the highest contributor of TP, with a current load of 42.86 lbs/day.

Table 15. NPDES facilities that currently discharge more than 10 lbs/day of TP in the Arkansas River Watershed from Hutchinson to Wichita.

Site	Kansas Permit No.	NPDES Permit No	Facility Name	Type	Current Flow (MGD)	Current TP Load (lbs/day)
SC524	M-AR49-IO01	KS0036188	Hutchinson Wastewater Treatment Plant	Municipal Mechanical Activated Sludge	4.76	13.07
SC524	M-AR82-OO02	KS0095711	South Hutchinson Wastewater Treatment Plant	Municipal Mechanical Activated Sludge	0.69	42.86

MS4 Permits: There are four municipal Separate Storm Sewer System (MS4) permits in the TMDL watershed (**Table 16**). Stormwater runoff from the City of Hutchinson is seen at the Yoder station (SC524) while runoff from KDOT-Sedgwick/Wichita, Sedgwick County, and the City of Wichita is seen in the Arkansas River at Wichita (SC758) watershed. MS4 permittees are expected to implement Best Management Practices (BMPs) to reduce, to the Maximum Extent Practicable (MEP), the discharge of TP to the Arkansas River during storm events.

Table 16. Municipal Separate Storm Sewer System Permits in the Arkansas River watershed from Hutchinson to Wichita.

Permitee	NPDES Permit #	KS Permit #	SC Site	Permit Expires
City of Hutchinson	KSR440009	M-AR49-SN01	SC524	1/31/19
KDOT- Sedgwick/Wichita	KSR410012	M-AR94-SU02	SC758	1/31/19
Sedgwick County	KSR410032	M-AR94-SU01	SC758	1/31/19
City of Wichita	KS0091049	M-AR94-SO01	SC758	7/31/19

Land Use: The land use of the Arkansas River watershed **(**SC523, SC5224, SC536, and SC758) is represented in **Figure 55.** Land use within the TMDL watershed is mostly cultivated crops (64.44%) and grassland/pasture (23.84%), according to the 2011 National Land Cover Data Set (NLCD) as represented in **Table 17**. Of the four SC sites of the watershed, SC536 has the largest fraction covered in cultivated crops (74.93%) and SC523 has more than half of its area under grassland and pasture (53.21%). The southernmost part of the TMDL watershed (SC758) comprises the highest percentage of developed land (43.35%) as a result of the high population and urban development in Sedgwick County.

Figure 55. Land use map for the Arkansas River Watershed from Hutchinson to Wichita (NLCD, 2011).

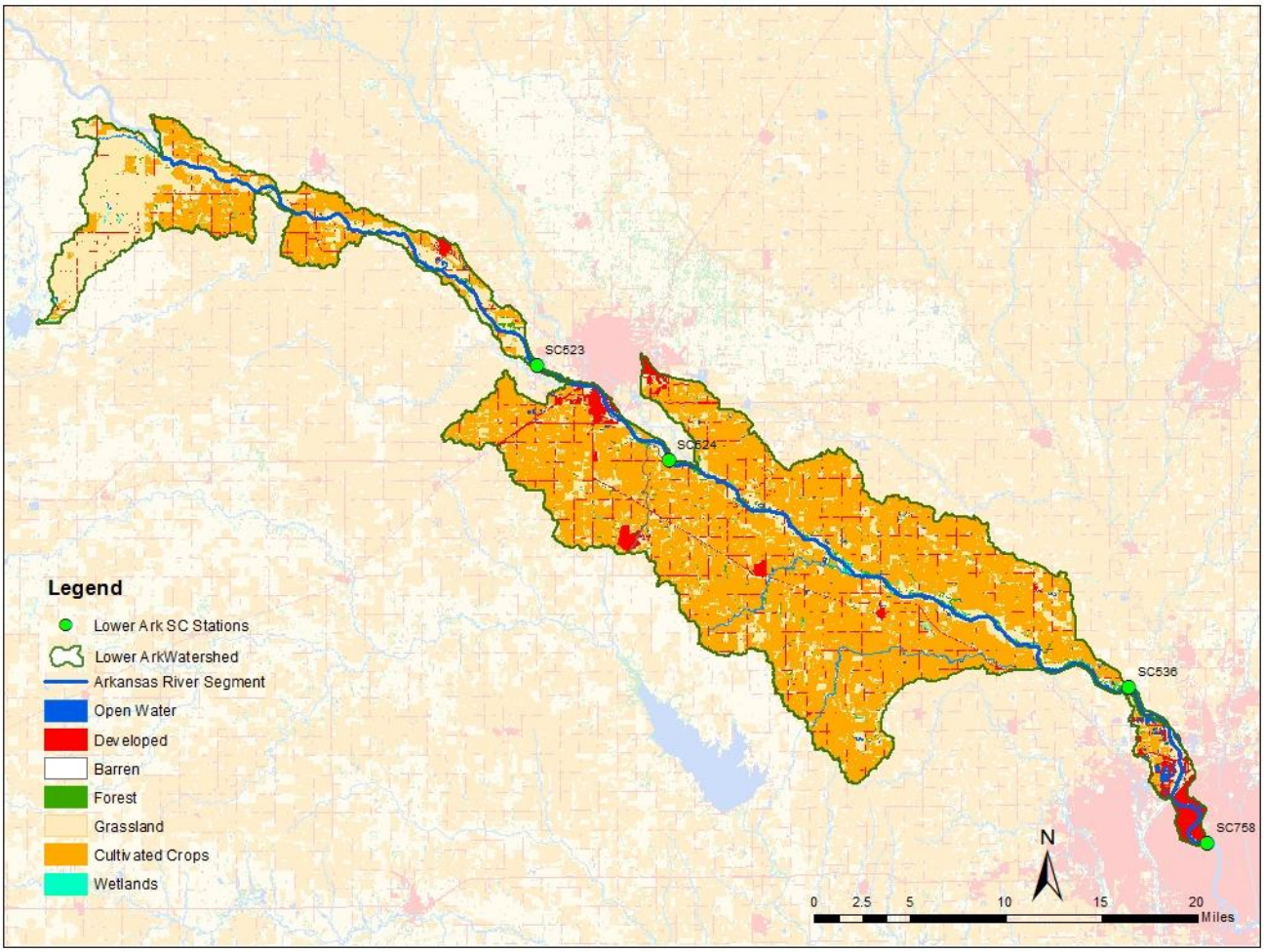


Table 17. Land use data for Arkansas River Watershed from Hutchinson to Wichita (NLCD, 2011).

Watershed	Approximate Land Area (acres)	Cultivated Crops	Grassland/ Pasture	Developed Land	Open Water	Forest	Wetlands	Barren Land
SC523	54,662	37.16%	53.21%	4.56%	2.39%	2.09%	0.57%	0.02%
SC524	36,598	71.07%	15.12%	11.00%	1.37%	1.13%	0.30%	0.01%
SC536	152,887	74.93%	15.63%	5.21%	1.59%	1.94%	0.67%	0.02%
SC758	8,024	20.13%	19.92%	43.35%	14.63%	1.19%	0.27%	0.27%
Total	**252,170**	**64.44%**	**23.84%**	**7.12%**	**2.15%**	**1.83%**	**0.58%**	**0.03%**

Livestock and Waste Management Systems: There are 41 certified or permitted confined animal feeding operations (CAFOs) within the TMDL watershed. Of the forty-one CAFOs, 5 are located in the SC523 watershed, fourteen are in the SC524 watershed and twenty-two are in the SC536 watershed. Three of the permits (A-ARRC-H001, A-ARRC-C005, and A-LAHV-H001) are large enough to require a federal permit. All of these livestock facilities have waste management systems designed to minimize runoff entering their operation and detain runoff emanating from their facilities. These facilities are designed to retain a 25-year, 24-hour rainfall/runoff event as well as an anticipated two weeks of normal wastewater from their operations. Typically, this rainfall event coincides with streamflow that occurs less than 1-5% of the time. It is unlikely TP loading would be attributable to properly operating

permitted facilities, though extensive loading may occur if any of these facilities were in violation and discharged. **Table 18** details the CAFO facilities within the TMDL watershed.

Table 18. Registered or Permitted Animal Feeding Operations in the Arkansas River Watershed.

SC Site	KS Permit #	County	Animal Total	Permit Type	Animal Type (s)
SC523	A-ARRC-BA11	Rice	300	Certification	Beef
SC523	A-ARRC-BA12	Rice	140	Certification	Beef
SC523	A-ARRC-BA04	Rice	500	Certification	Beef
SC523	A-ARRC-H001	Rice	6,888	Permit	Swine
SC523	A-ARRC-C005	Rice	4,000	Renewal	Beef
SC524	N-ARRN-6327	Reno	0	Application	Beef
SC524	A-ARRN-BA10	Reno	425	Certification	Beef
SC524	A-ARRN-BA04	Reno	100	Certification	Beef
SC524	A-ARRN-BA08	Reno	700	Certification	Beef
SC524	A-ARRN-BA12	Reno	800	Certification	Beef
SC524	A-ARRN-M047	Reno	211	Permit	Dairy, Swine, Horses, Beef
SC524	A-ARRN-B009	Reno	300	Permit	Beef
SC524	A-ARRN-B010	Reno	116	Permit	Beef, Goats, Laying Hens NL
SC524	A-ARRN-M056	Reno	214	Renewal	Dairy
SC524	A-ARRN-M040	Reno	90	Renewal	Dairy
SC524	A-ARRN-M054	Reno	55	Renewal	Dairy
SC524	A-ARRN-S016	Reno	1,949	Renewal	Swine, Goats, Sheep
SC524	A-ARRN-M003	Reno	410	Renewal	Dairy
SC524	A-ARRN-M046	Reno	150	Renewal	Dairy
SC536	N-ARRN-6234	Reno	45	Application	Dairy
SC536	A-ARRN-MA07	Reno	50	Certification	Dairy
SC536	247	Reno	48	Certification	Dairy, Horses
SC536	A-ARRN-MA14	Reno	21	Certification	Dairy
SC536	A-ARRN-LA01	Reno	150	Certification	Sheep
SC536	A-ARRN-BA07	Reno	300	Certification	Beef
SC536	A-ARRN-BA17	Reno	600	Certification	Beef
SC536	A-ARRN-BA05	Reno	150	Certification	Beef
SC536	A-ARRN-LA02	Reno	200	Certification	Sheep, Beef
SC536	A-ARRN-BA11	Reno	300	Certification	Beef
SC536	A-ARRN-M012	Reno	62	Permit	Dairy
SC536	A-ARRN-M010	Reno	110	Permit	Dairy, Beef
SC536	A-ARRN-M043	Reno	102	Permit	Dairy, Beef, Horses
SC536	A-ARRN-M026	Reno	113	Permit	Dairy, Beef, Sheep, Horses
SC536	A-ARRN-M048	Reno	40	Permit	Dairy
SC536	A-ARRN-M044	Reno	85	Permit	Dairy
SC536	A-LAHV-H001	Harvey	4,800	Permit	Swine
SC536	A-ARRN-B011	Reno	850	Permit	Beef
SC536	A-ARSG-M044	Sedgwick	275	Permit	Dairy, Beef
SC536	A-ARRN-B001	Reno	200	Permit	Beef

SC Site	KS Permit #	County	Animal Total	Permit Type	Animal Type (s)
SC536	A-ARRN-M041	Reno	162	Renewal	Dairy, Horses, Beef
SC536	A-ARRN-M022	Reno	35	Renewal	Dairy

According to the United States Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS) Kansas 2012 report, there were 79,307 and 48,298 head of cattle (including calves) in Reno and Rice counties, respectively. Those are the two counties within the watershed with the most cattle. The number of cattle from 2007 to 2012 showed a decreasing trend in all the counties. Swine production showed a decreasing trend in all counties except Rice County, which had an increase of 22% from 2007 to 2012. Harvey, Reno, and Sedgwick counties reported positive trends in poultry production. The number of sheep reported in Sedgwick County in 2012 was more than double the number reported in 2007. The number of animals reported in 2007 and 2012 in the Arkansas River Watershed, and the percentage change in these numbers, are shown in **Table 19**.

Table 19. Number of cattle, poultry, dairy, horses, sheep, swine and goats in the counties within the Arkansas River Watershed.

County	Year	Cattle and Calves	Poultry (Layers*)	Dairy	Horses	Sheep and Lambs	Swine	Goats
Harvey	2012	35,702	1,073	1,028	717	547	12,989	439
	2007	39,773	762	591	1,115	764	22,775	687
	Change in %	-10	41	74	-36	-28	-43	-36
Reno	2012	79,307	3,684	2,855	2,311	3,396	14,191	1,221
	2007	86,582	2,508	2,795	3,024	4,345	17,129	1,670
	Change in %	-8	47	2	-24	-22	-17	-27
Rice	2012	48,298	(D)	56	499	325	13,473	308
	2007	57,799	(D)	(D)	816	324	11,020	324
	Change in %	-16	NA	NA	-39	0	22	-5
Sedgwick	2012	29,784	1,624	1,902	2,220	3,034	1,990	819
	2007	34,551	1,540	2,718	2,359	1,471	3,336	1,219
	Change in %	-14	5	-30	-6	106	-40	-33

*Layers: This category includes table-egg type layers, hatching layers for meat-types, hatching layers for table-egg types, and reported bantams.

On-Site Waste Systems: The majority of the households in the Arkansas River Watershed are connected to public sewer systems. According to the Spreadsheet Tool for Estimating Pollutant Loads (STEPL), there are 2,151 septic systems in the TMDL watershed. The estimated septic failure rate in Kansas is somewhere in the 10-15% range, according to a survey performed by the Electric Power Research Institute. Failing on-site septic systems have the potential to contribute to nutrient loading in the watershed. However, because of their relatively small number, their small flows, and the proclivity of phosphorus for adsorbing to soil, failing on-site septic systems would be a minor source of phosphorus loading within the watershed and would not significantly contribute to phosphorus impairment in the Arkansas River Watershed.

Population Density: According to the 2010 Census Block information, the TMDL watershed has approximately 22,044 people, giving a population density of 57 people/square mile. This population does not account for the City of Hutchinson as it physically lies outside the TMDL watershed. However, with the inclusion of the City of Hutchinson, the population adds up to 58,125 people, giving a population density of 141 people/square mile. The City of Hutchinson is considered in the TMDL watershed, as both the municipal water treatment facility and the MS4 facility in Hutchinson drain to the

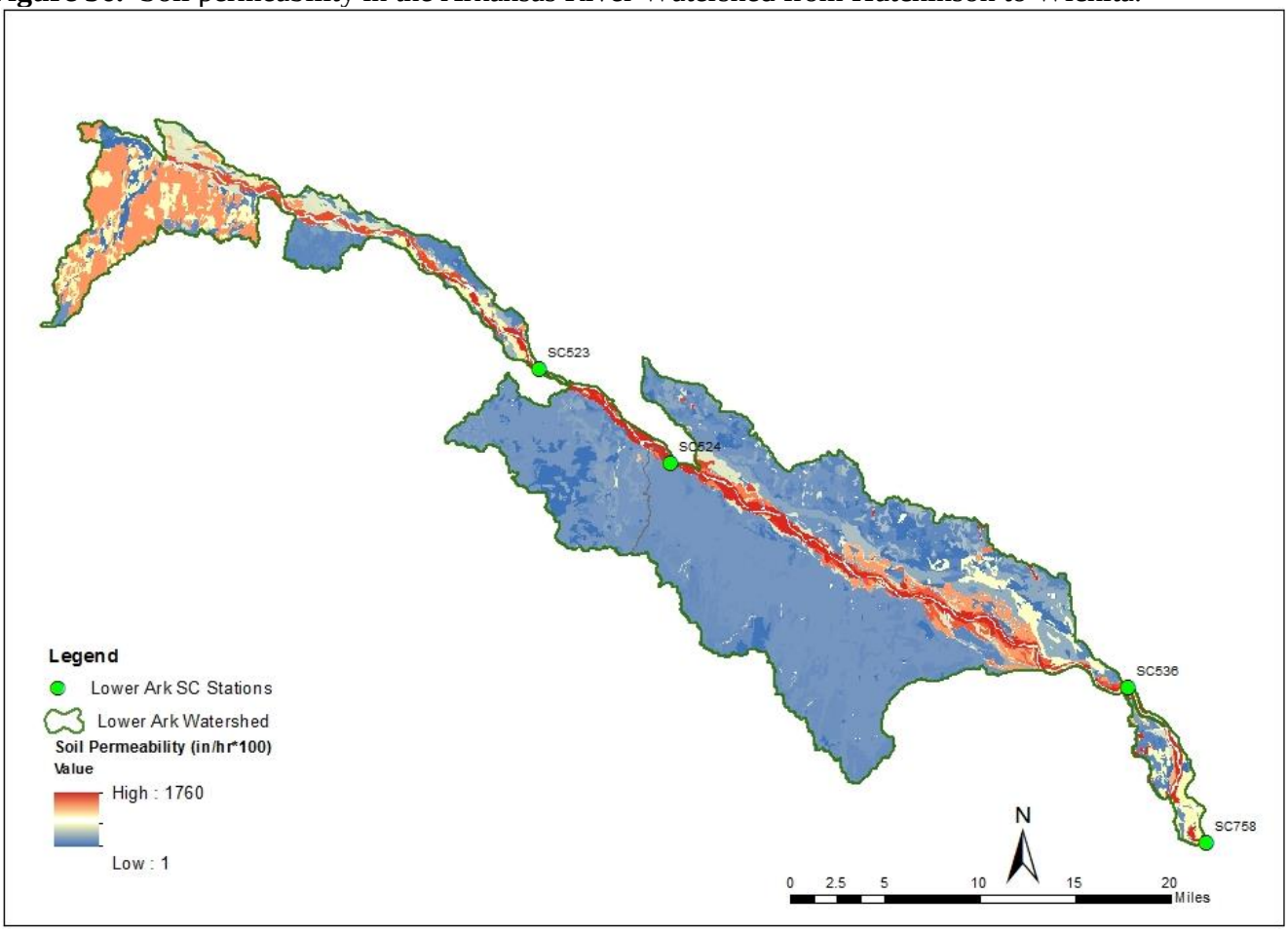
SC524 watershed. There are several additional cities and municipalities within the watershed; these are detailed in **Table 20**. Populations within the incorporated areas of the watershed are growing, according to the 2000 and 2010 census results; growth in the watersheds is expected to continue with a 12% increase in population in the Arkansas River Watershed by 2040.

Table 20. U.S. Census results and a 2040 population projection from the Kansas Water Office (KWO) for cities in the Arkansas River Watershed.

City	2000 U.S. Census	2010 U.S. Census	% Change 2000 to 2010	2040 Population Projection (KWO)	% Projected Population Growth 2010 to 2040
Nickerson	1,192	1,259	6%	1,462	16%
Hutchinson	41,437	43,225	4%	48,588	12%
South Hutchinson	2,613	2,712	4%	3,011	11%
Haven	1,248	1,288	3%	1,406	9%
Mount Hope	825	847	3%	914	8%
Bentley	417	463	11%	603	30%
Total	**47,732**	**49,794**	**4%**	**55,984**	**12%**

Contributing Runoff: The Arkansas River Watershed has a mean soil permeability of 8.48, 1.85, 2.39, and 5.78 inches/hour in the SC523, SC524, SC536, and SC758 watersheds, respectively, according to NRCS STATSGO database (**Figure 56**). Permeability in the Arkansas River Watershed from Hutchinson to Wichita ranges from 0.01 to 17.6 inches/hour. In the SC523 watershed, about 84% of the watershed has high permeability values of 13 inches/hour. Only about 26% of the SC523 watershed has a higher permeability rate of 17 inches/hour but 55% has a permeability rate below 1.67 inches/hour. Nearly 65% of the SC536 watershed has permeability values of 7.48 inches/hour or lower. 32% of the SC758 watershed has a high permeability of 13 inches/hour but 54% of the watershed has a lower permeability rate of 6.92 inches/hour or lower. According to a USGS open-file report (Juracek, 2000), threshold soil permeability values are set at 3.43 inches/hour for very high, 2.86 inches/hour for high, 2.29 inches/hour for moderate, 1.71 inches/hour for low, 1.14 inches/hour for very low, and 0.57 inches/hour for extremely low soil permeability. Runoff is primarily generated as infiltration excess when rainfall intensity is greater than soil permeability. As the watersheds' soil profiles become saturated, excess overland flow is produced. The majority of the nonpoint-source nutrient runoff will be associated with cropland areas throughout the watershed that are in close proximity to the stream corridors.

Figure 56. Soil permeability in the Arkansas River Watershed from Hutchinson to Wichita.



Background: Phosphorus is present over the landscape, in the soil profile as well as terrestrial and aquatic biota. Wildlife can contribute phosphorus loadings, particularly if they congregate to a density that exceeds the assimilative capacity of the land or water.

4. ALLOCATION OF POLLUTANT REDUCTION RESPONSIBILITY

The endpoints for these TMDLs are based on the biological condition, pH, sestonic chlorophyll-*a*, and dissolved oxygen concentrations, all of which should improve to a level of full attainment of designated uses as phosphorus concentrations decrease in the river.

This TMDL is established as protective for the Arkansas River at Hutchinson (SC523) and its associated segments, hence, Phase I and Phase II total phosphorus management milestones are established at the current median TP of 0.096 mg/L. Arkansas River CUSEGA 110300101 is monitored by three stream chemistry stations: SC524 (Yoder), SC536 (Maize), and SC758 (Wichita) and stretches from above SC524 to its terminus at its confluence with the Little Arkansas River at Wichita just below SC758. Although Phase I and Phase II milestones are established upstream at the impaired station at Yoder (SC524) and the unimpaired station at Maize (SC536), the ultimate TMDL for this segment is established at its terminus as measured at SC758. Phase I and Phase II TP milestones for SC758 are set at the current median of 0.125 mg/L TP. At Yoder (SC524), the Phase I and Phase II milestones reflect the Level III Ecoregion 27 station median and first quartile values of 0.200 mg/L and 0.130 mg/L TP,

respectively. Phase I management milestone at Maize (SC536) is established at the current station median of 0.192 mg/L and Phase II reflects the ecoregional value of 0.130 mg/L TP.

The Phase I TMDL at Yoder (SC524) will require point source load reductions from the mechanical wastewater treatment plant operated by the City of South Hutchinson. In addition, it is expected that best management practices prescribed in the MS4 permits will be implemented by the permitted entities to the maximum extent practicable during precipitation events. Furthermore, the application of riparian and livestock agricultural best management practices in the Arkansas River watershed from Hutchinson to Wichita should continue to abate and reduce total phosphorus loading from nonpoint sources.

Once the concentrations in the Arkansas River at SC524 approach the Phase I milestones of a median TP concentration of 0.200 mg/L, an intensive assessment of macroinvertebrate abundance and diversity will be performed to determine compliance with the narrative nutrient criteria. Presuming one or more of the numeric endpoints are not met at the end of Phase I, Phase II will commence with a TP milestone of 0.130 mg/L at Yoder (SC524) and Maize (SC536) with additional reductions in loads and phosphorus concentrations accomplished through enhanced implementation of controls on both point and nonpoint sources throughout the Arkansas River watershed from Hutchinson (SC523) to Wichita (SC758).

Point Sources: The Phase I wasteload allocations (WLA) associated with the facilities discharging in the watershed are detailed in **Table 21**. A complete list of NPDES permitted facilities in the TMDL watersheds can be found in **Appendix A.** The three concrete plants are assigned Phase I and Phase II wasteload allocations of zero as they are not expected to contribute to the phosphorus loads in their respective watersheds. The City of Wichita drinking water plant, the former Farmland Industries groundwater remediation site, and the three industrial facilities (Sonoco, Morton, and Marina Point) have Phase I and Phase II wasteload allocations established at a nominal TP concentration of 0.2 mg/L and facility design flow, as they are expected to contribute only nominal phosphorus loads to their respective watersheds.

Wasteload allocations for the five municipal lagoon systems treating waste for the cities of Nickerson, Alden, and Haven, as well as the Reno County Sewer District No. 202 and the Fun Valley Wastewater Treatment Lagoons have Phase I and Phase II wasteload allocations calculated using facility design flow and 2 mg/L TP, an effluent TP concentration commonly seen from Kansas lagoon systems.

Phase I wasteload allocations for the City of Hutchinson and the City of South Hutchinson, the two municipal mechanical facilities discharging to the TMDL watershed, were calculated at a total phosphorus concentration of 1 mg/L at facility design flow. For Phase II, the two municipal mechanical treatment facilities may need to implement enhanced nutrient reduction (ENR) technologies in order to meet their Phase II WLA calculated at a TP concentration of 0.5 mg/L and facility design flow.

In addition, a WLA of 12.64 lbs/day totaling 4,613.60 lbs/year TP has been reserved at SC758 in anticipation of further development in the Arkansas River Watershed from Hutchinson to Wichita. This reserve may be portioned and applied to new or expanded NPDES permitted facilities discharging to any one of the SC523, SC524, SC536, or SC758 watersheds during either phase of TMDL implementation.

Table 21. Phase I wasteload allocations for facilities permitted to discharge to the Arkansas River from Hutchinson to Wichita. *no design flow established in NPDES permit.

SC Site	Permit #	Permitee	Design Flow (MGD)	Phase I Anticipated TP Concentration (mg/L)	Phase I TP WLA (lbs/day)	Phase I TP WLA (lbs/year)
SC523	I-AR66-PR01	Gravel & Concrete, Inc.	*	0	0	0
	M-AR66-OO02	City of Nickerson	0.1755	2	2.93	1,069.45
	M-AR02-OO01	City of Alden	0.024	2	0.40	146.00
	M-AR49-OO01	Fun Valley WW Treatment Lagoons	0.0076	2	0.13	47.45
Phase I Wasteload Allocation for the Lower Arkansas River Watershed near Hutchinson (SC523)					*3.46*	*1,262.90*
SC524	I-AR82-PO01	Morton International	5.55	0.2	9.27	3,383.55
	I-AR82-PO15	Former Farmland Industries – South Hutchinson	0.216	0.2	0.36	131.40
	I-AR82-PR01	Mid America Redi-Mix – Hutchinson	*	0	0	0
	M-AR49-IO01	City of Hutchinson	8.3	1	69.34	25,309.10
	M-AR82-OO02	City of South Hutchinson	2	1	16.71	6,099.15
Phase I Wasteload Allocation for the Lower Arkansas River Watershed near Yoder (SC524)					*95.68*	*34,923.20*
SC536	I-AR49-CO04	Sonoco – Hutchinson Mill LLC	0.055	0.2	0.09	32.85
	I-AR49-PR01	Concrete Enterprises, Inc.	*	0	0	0
	I-AR98-PO01	Reno Co. Sewer District #202	0.02	2	0.33	120.45
	M-AR41-OO01	City of Haven	0.2488	2	4.16	1,518.40
Subtotal Phase I Wasteload Allocation for the Lower Arkansas River Watershed near Maize (SC536)					*4.58*	*1,671.70*
SC758	I-AR94-CO63	Marina Point Office Park	0.234	0.2	0.39	142.35
	I-AR94-PO10	City of Wichita Water Plant	0.72	0.2	1.20	438.00
Phase I Wasteload Allocation for the Lower Arkansas River Watershed at Wichita (SC758)					*1.59*	*580.35*
Reserve Wasteload Allocation					12.64	4,613.60
Total Phase I Wasteload Allocation for the Lower Arkansas River Watershed from Hutchinson (SC523) to the terminus of segment 110300101 at Wichita (SC758)					**117.95**	**43,051.75**

Figures 57-60 display current seasonal loading, the Phase I TMDL and load and wasteload allocations at KDHE stream chemistry stations on the Arkansas River near Hutchinson (SC523), Yoder (SC524), Maize (SC536), and Wichita (SC758). Current condition, Phase I and II load, wasteload, and stormwater (MS4) allocations for each station can be seen in **Tables 22-25**. The reserve wasteload and MS4 allocations for the Hutchinson (SC523) to Wichita (SC758) watershed is also displayed in **Table 25.**

Calculated load capacities in Figures 57-60 and Tables 22-25 are based on total phosphorus management milestones and the estimated flow conditions in the river. Upstream loading capacity can be subtracted from downstream loading capacity to assess incremental loading along the reaches of the river.

Figure 57. Phase I TMDL for the Arkansas River at Hutchinson (SC523) with wasteload allocation, load allocation and seasonal loads displayed.

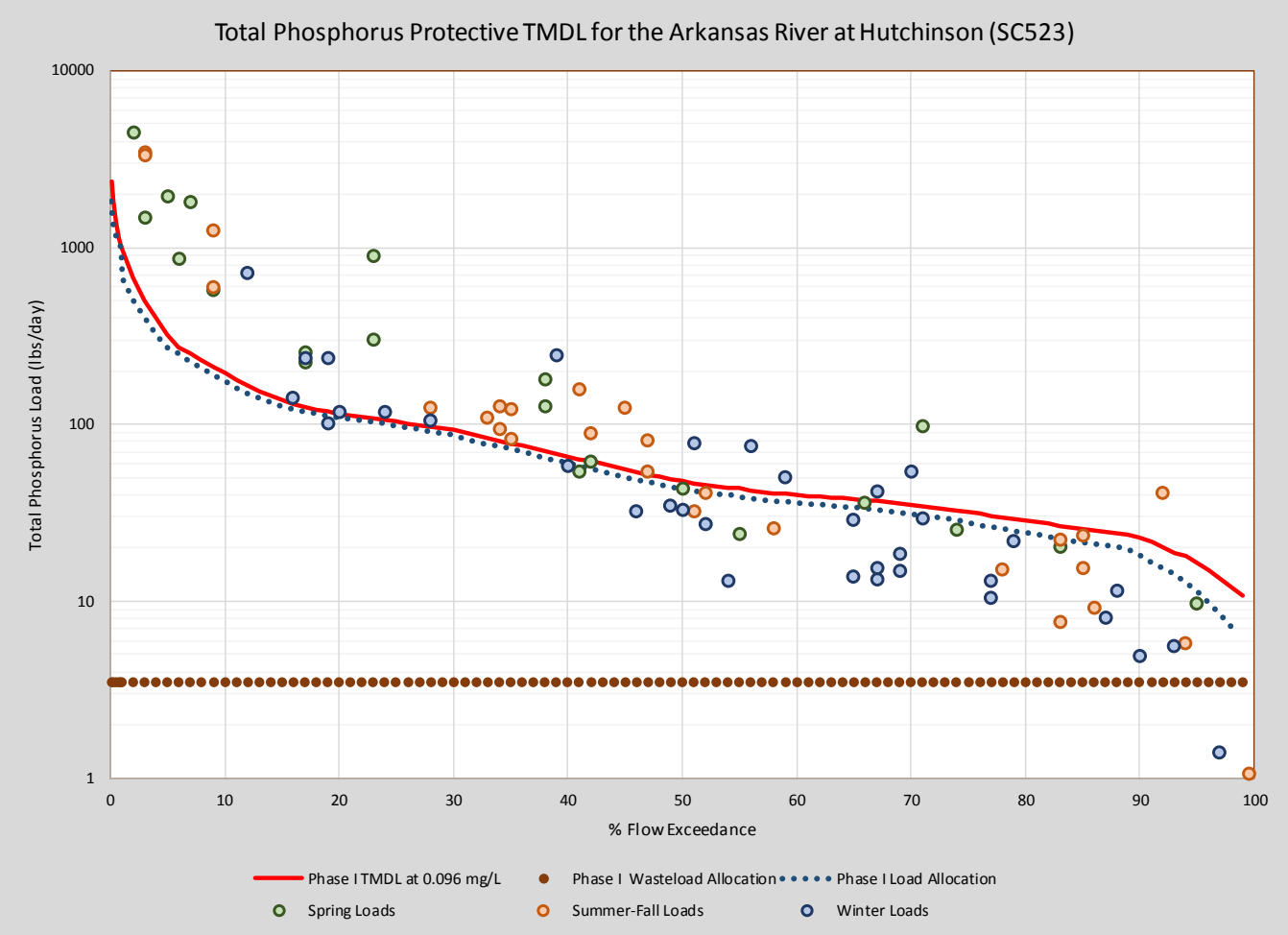


Table 22. Load capacity (TMDL), wasteload, and load allocations for the Arkansas River at Yoder (SC524) watershed.

Percent Flow Exceedance	Flow at SC523	Current Condition (lbs/day)	Load Capacity (lbs/day)	Wasteload Allocation (lbs/day)	Load Allocation (lbs/day)
Phase I					
90%	44.42	23.03	23.03	3.46	19.57
75%	62.02	32.15	32.15	3.46	28.69
50%	92.14	47.76	47.76	3.46	44.30
25%	202.08	104.76	104.76	3.46	101.30
10%	374.35	194.06	194.06	3.46	190.60
Phase II					
90%	44.42	23.03	23.03	3.46	19.57
75%	62.02	32.15	32.15	3.46	28.69
50%	92.14	47.76	47.76	3.46	44.30
25%	202.08	104.76	104.76	3.46	101.30
10%	374.35	194.06	194.06	3.46	190.60

Figure 58. Phase I TMDL for the Arkansas River at Yoder (SC524) with wasteload allocation, load allocation and seasonal loads displayed.

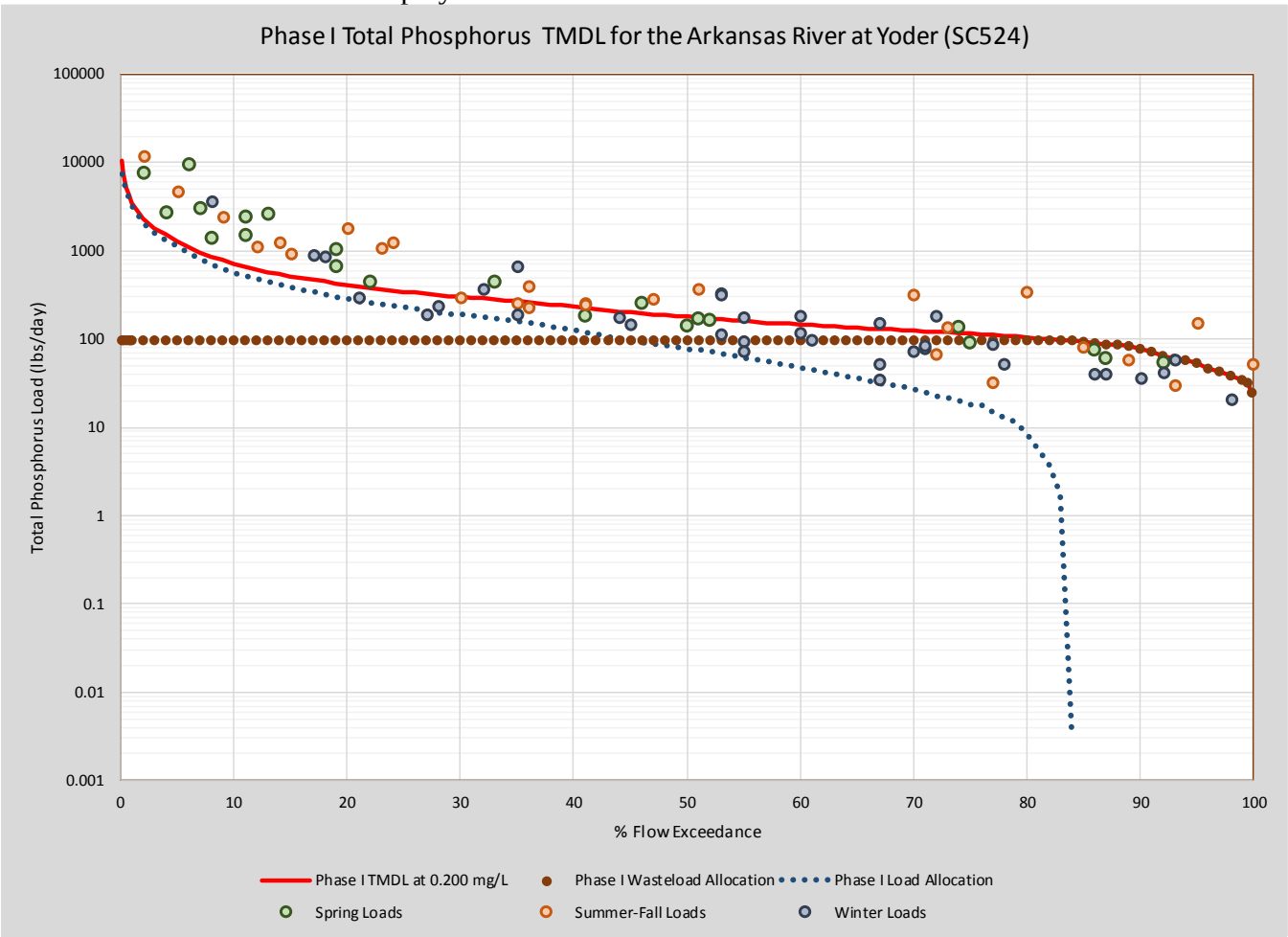


Table 23. Phase I and II load capacity (TMDL), and wasteload, MS4 and load allocations in the Arkansas River at Yoder (SC524) watershed.

Percent Flow Exceedance	Flow at SC524 (cfs)	Current Condition (lbs/day)	Load Capacity (lbs/day)	Wasteload Allocation (lbs/day)	MS4 Allocations (lbs/day)	Load Allocation (lbs/day)
Phase I						
90%	72.56	83.07	78.37	78.37	0.00	0.00
75%	106.99	122.48	115.54	95.68	2.00	17.86
50%	165.59	189.57	178.84	95.68	6.65	76.51
25%	318.86	365.03	344.37	95.68	19.90	228.79
10%	656.05	751.05	708.54	95.68	49.03	563.83
Phase II						
90%	72.56	83.07	50.94	50.94	0.00	0.00
75%	106.99	122.48	75.10	52.66	1.00	21.44
50%	165.59	189.57	116.25	52.66	5.72	57.87
25%	318.86	365.03	223.84	52.66	15.41	155.77
10%	656.05	751.05	460.55	52.66	36.71	371.18

Figure 59. Phase I TMDL for the Arkansas River at Maize (SC536) with wasteload allocation, load allocation and seasonal loads displayed.

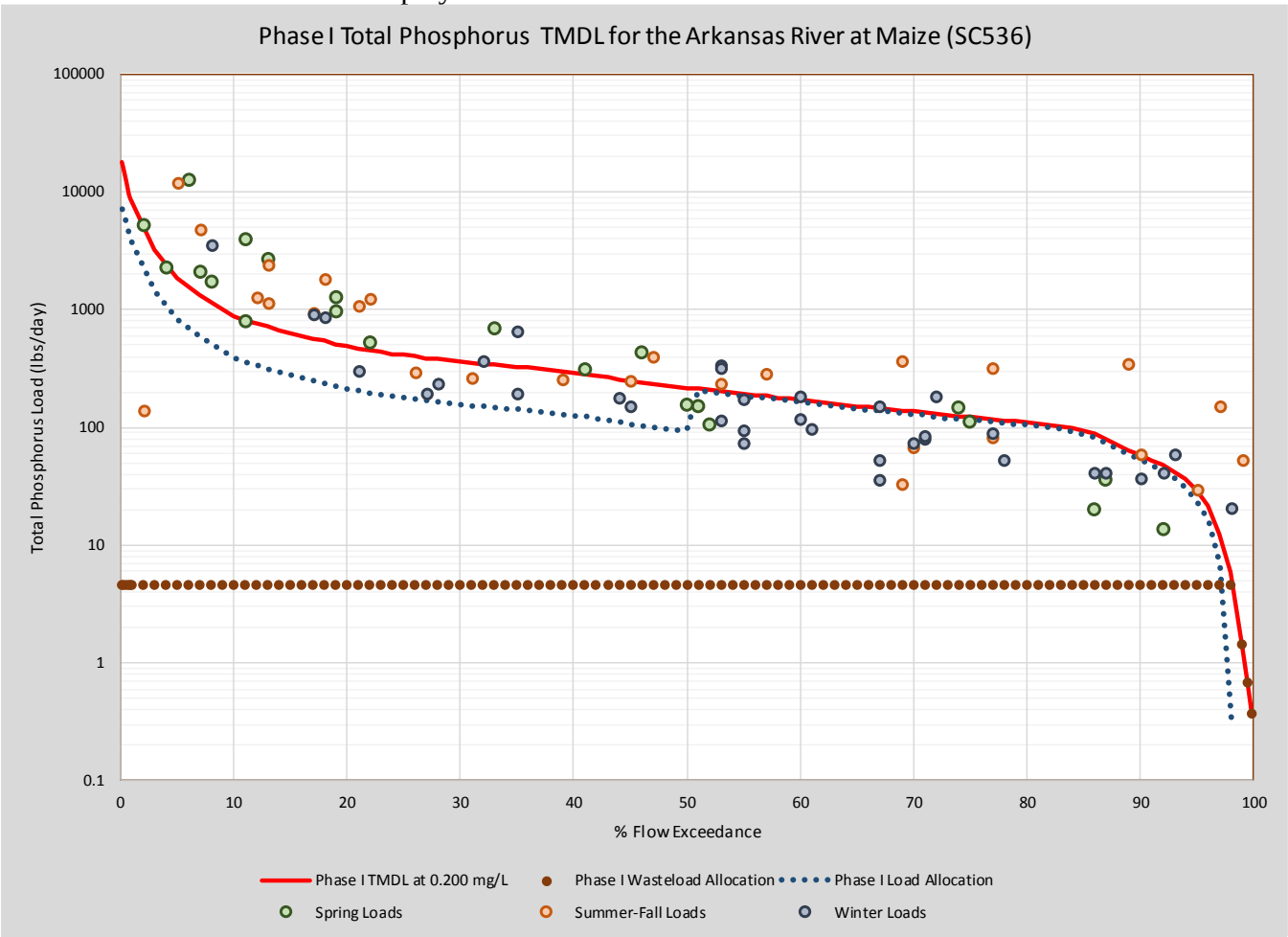


Table 24. Phase I and II load capacity (TMDL), and wasteload, MS4 and load allocations in the Arkansas River at Maize (SC536) watershed.

Percent Flow Exceedance	Flow at SC536 (cfs)	Current Condition (lbs/day)	Load Capacity (lbs/day)	Wasteload Allocation (lbs/day)	MS4 Allocations (lbs/day)	Load Allocation (lbs/day)
Phase I						
90%	56.88	58.97	58.97	4.58	1.00	53.39
75%	117.95	122.29	122.29	4.58	2.00	115.71
50%	209.91	217.63	217.63	4.58	119.31	93.74
25%	398.83	413.50	413.50	4.58	229.00	179.92
10%	858.92	890.53	890.53	4.58	496.13	389.82
Phase II						
90%	56.88	58.97	39.93	4.58	1.00	34.35
75%	117.95	122.29	82.80	4.58	2.00	76.22
50%	209.91	217.63	147.36	4.58	54.25	88.53
25%	398.83	413.50	279.98	4.58	104.65	170.75
10%	858.92	890.53	602.96	4.58	227.39	370.99

Figure 60. Phase I load capacity (TMDL), wasteload allocation, and load allocation across the flow duration curve for the Arkansas River at CUSEGA 110300101 terminus, as measured at SC758, with seasonal loads displayed.

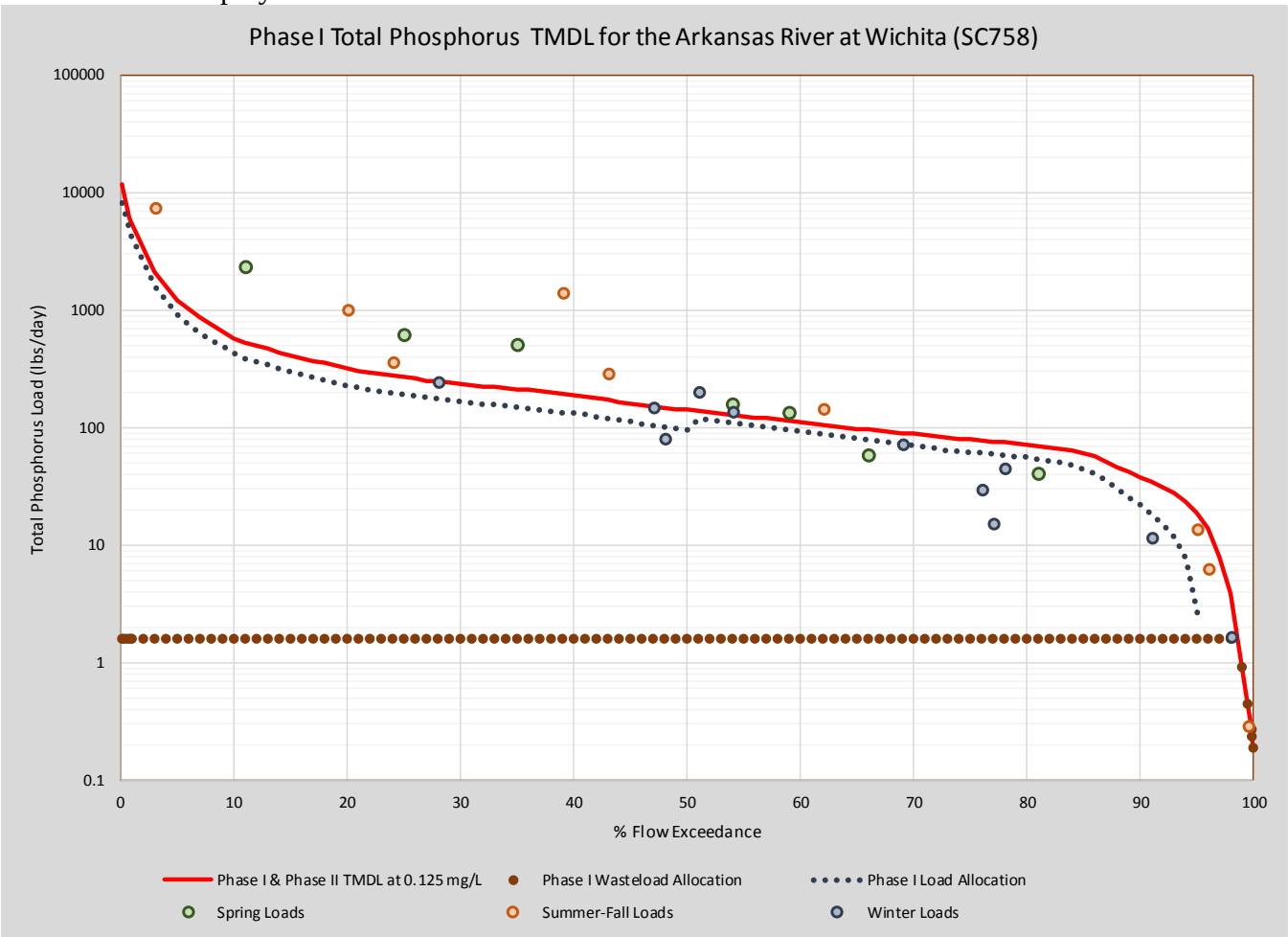


Table 25. Phase I and II load capacity (TMDL), and wasteload, MS4 and load allocations in the Arkansas River at Wichita (SC758) watershed.

Percent Flow Exceedance	Flow at SC758 (cfs)	Current Condition (lbs/day)	Load Capacity (lbs/day)	Wasteload Allocation (lbs/day)	Reserve Wasteload Allocation (lbs/day)	MS4 Allocations (lbs/day)	Reserve MS4 Allocation (lbs/day)	Load Allocation (lbs/day)
Phase I								
90%	56.69	38.27	38.27	1.59	12.64	1.00	1.00	22.04
75%	118.05	79.68	79.68	1.59	12.64	2.00	2.00	61.45
50%	210.09	141.81	141.81	1.59	12.64	6.38	24.24	96.96
25%	399.16	269.43	269.43	1.59	12.64	12.76	51.04	191.40
10%	859.65	580.26	580.26	1.59	12.64	28.30	113.21	424.52
Phase II								
90%	56.69	22.04	38.27	1.59	12.64	1.00	1.00	22.04
75%	118.05	61.45	79.68	1.59	12.64	2.00	2.00	61.45
50%	210.09	96.96	141.81	1.59	12.64	11.48	23.22	92.88
25%	399.16	191.40	269.43	1.59	12.64	22.97	46.45	185.78
10%	859.65	424.52	580.26	1.59	12.64	50.94	103.02	412.07

Nonpoint Source Load Allocation: The load allocation for nonpoint sources is the remaining load capacity after wasteloads and reserve wasteloads for NPDES wastewater and MS4 stormwater have been accounted for in. Nonpoint sources are assumed to be minimal during low flow conditions. The load allocation grows proportionately as normal conditions occur and the load allocation continues to increase with wet weather conditions, thereby accounting for increased runoff from contributing areas. Phase I and II load allocations in the Hutchinson (SC523) and Wichita (SC758) watersheds and Phase I load allocations in the Maize (SC536) watershed are intended to be protective of the current condition of total phosphorus loading to the watershed. The Phase I and Phase II nonpoint source reductions in phosphorus loading for the Yoder (SC524) and Phase II nonpoint source reductions in phosphorus loading for the Maize (SC536) watershed are expected to be achieved by implementation of agricultural best management practices in the contributing areas of the watershed.

MS4 Stormwater: There are no MS4 permits in the SC523 watershed, hence no MS4 wasteload was developed for the protective TMDL for the Arkansas River at Hutchinson. The wasteload allocation for the City of Hutchinson, KDOT-Sedgwick/Wichita, City of Wichita, and Sedgwick County MS4 permits is provided by proportioning the remaining load capacity, after accounting for the NPDES WLA and reserve WLA, between MS4 and nonpoint source loads. This was done by assuming MS4 load contributions would arise from the developed areas within the watershed. Thus, the MS4 WLA considers the proportion of developed land (open space and low, medium and high intensity) in the contributing areas of SC524, SC536, and SC758 at 11%, 5.2%, and 43%, respectively. Runoff volume during precipitation events in each of the contributing areas was estimated using Wiki Watershed: Model My Watershed with the precipitation value set at the model's default value of 2.5 cm. The Phase I runoff TP load for the SC524, SC536, and SC758 watersheds was calculated using their respective Phase I TP management milestones of 0.200, 0.192, and 0.125 mg/L. These loads were then multiplied by 23%, the percentage of time rain falls in the watershed (NOAA USW00013986 1996-2017) with the resulting load multiplied by the percentage of developed land in the watersheds. Each watershed's load was then compared to the load allocation at 50% flow exceedance at the respective station showing the calculated runoff load to be 9%, 56%, and 5% of the remaining load capacity each station during Phase I. The Phase II MS4 allocation was calculated the same way using the Phase II TP milestones of 0.130 mg/L at Yoder (SC524) and Maize (SC536) and 0.125 mg/L at Wichita (SC758) resulting in runoff loads estimated at 8%, 38%, and 9% of the remaining load at 50% flow exceedance at each station. During both phases, nominal MS4 allocations of 1 lb/day and 2 lb/day for Arkansas River flows ranging from 76 to 100 and 51 to 75 percent flow exceedance, respectively, have been assigned to account for incidences of localized heavy rainfall that may generate runoff conditions when the river is at or below median flow. In addition, a reserve MS4 wasteload allocation calculated at 20% of the remaining load at the downstream Wichita (SC758) station has been established to accommodate growth and may be portioned and applied to any of the MS4 permits in the SC524, SC536, or SC758 watershed during either phase of TMDL implementation. MS4 permitees are expected to reduce phosphorus loading using best management practices to the maximum extent practicable.

Defined Margin of Safety: The Margin of Safety provides some hedge against the uncertainty in phosphorus loading into the Arkansas River. This TMDL uses an implicit margin of safety, relying on conservative assumptions. Firstly, there are five endpoints that are established by this TMDL. Secondly, the sestonic chlorophyll *a* and biological endpoints used to assess compliance with the narrative criteria have to be maintained for three consecutive years before attainment of water quality standards can be claimed. Third, because there is often a synergistic effect of phosphorus and nitrogen on in-stream biological activity, concurrent efforts by municipal wastewater treatment facilities to reduce nitrogen content of its wastewater should complement the effect of phosphorus load reduction in

improving the biological condition of the Arkansas River. In addition, wasteloads were conservatively set by using design flow for municipal facilities although most are discharging well under design flow and some wastewater treatment facilities were assigned wasteloads when it is likely that several do not contribute any nutrient loads. Furthermore, total phosphorus TMDL development for the watersheds of the tributaries to the Lower Arkansas River is scheduled for 2020. Implementation of those TMDLs will support total phosphorus load reductions in the main stem Little Arkansas and Lower Arkansas Rivers.

State Water Plan Implementation Priority: Early implementation of this TMDL will focus on wastewater treatment at the major municipal wastewater treatment facilities in the watershed along with riparian management to effectively reduce the phosphorus loading to the Arkansas River. Additionally further reduction in phosphorus loads will occur along with implementation of stormwater abatement practices. Due to the need to reduce the high nutrient loads in the watershed, this TMDL will be **High** Priority for implementation.

Nutrient Reduction Framework Priority Ranking: Most of the TMDL watershed lies within the Gar-Peace Subbasin (HUC8: 11030010) which is among the top sixteen HUC8s targeted for state action to reduce nutrients.

Priority HUC12s: Although this TMDL is initially driven by implementation of point source treatment improvements, priority HUC12s within the watershed can be identified based on the cropland areas adjacent to the streams within the watershed. Priority HUC 12s are based on HUC12s with the highest pounds per year per acre of loading as estimated by STEPL (**Table 26**).

Table 26. HUC12 land use and estimated total phosphorus load based on land use. High priority HUC12s for total phosphorus (TP) reduction are highlighted in beige.

HUC 12	Urban	Cropland	Pasture and Grazing Land	Forest	Total	TN	TP	TN	TP	SC Site
	acres					*lbs/year*		*lbs/acre/year*		
110300090407	13	1,845	16,245	99	18,202	43,618	6,233	2.40	0.342	SC523
110300100101	14	9,456	6,011	264	15,746	92,213	18,957	5.86	1.204	SC523
110300100108	348	9,050	6,866	628	16,892	94,642	19,068	5.60	1.129	SC523
110300100201	1,638	25,049	5,356	346	32,389	219,452	50,878	6.78	1.571	SC524
110300100202	233	15,006	3,996	664	19,899	140,925	33,441	7.08	1.681	SC536
110300100203	982	28,298	5,953	765	35,998	263,524	63,014	7.32	1.750	SC536
110300100204	205	16,831	4,309	663	22,008	157,562	36,641	7.16	1.665	SC536
110300100205	66	23,044	3,292	262	26,664	204,394	49,263	7.67	1.848	SC536
110300100206	264	23,970	3,378	221	27,832	215,256	52,140	7.73	1.873	SC536
110300100207	135	8,790	3,361	501	12,787	87,775	19,117	6.86	1.495	SC536
110300100208	2,381	2,026	1,913	93	6,414	39,527	7,130	6.16	1.112	SC758

Priority HUC12s for total phosphorus reduction appear as dark brown in **Figure 61** and are identified as: 110300100201;110300100206; 110300100205; 110300100204; 110300100203; and 110300100202. Although this TMDL does not establish a load reduction for total nitrogen, priority HUC12s for nitrogen reduction have been identified in order to provide Watershed Restoration and Protection Strategy (WRAPS) groups with additional information in targeting areas for nutrient reduction in their watershed. Priority HUC12s for total nitrogen reduction appear as dark green in **Figure 62** and mirror those identified as high priority for total phosphorus reduction.

Figure 61. STEPL results for total phosphorus loading in the TMDL watershed.

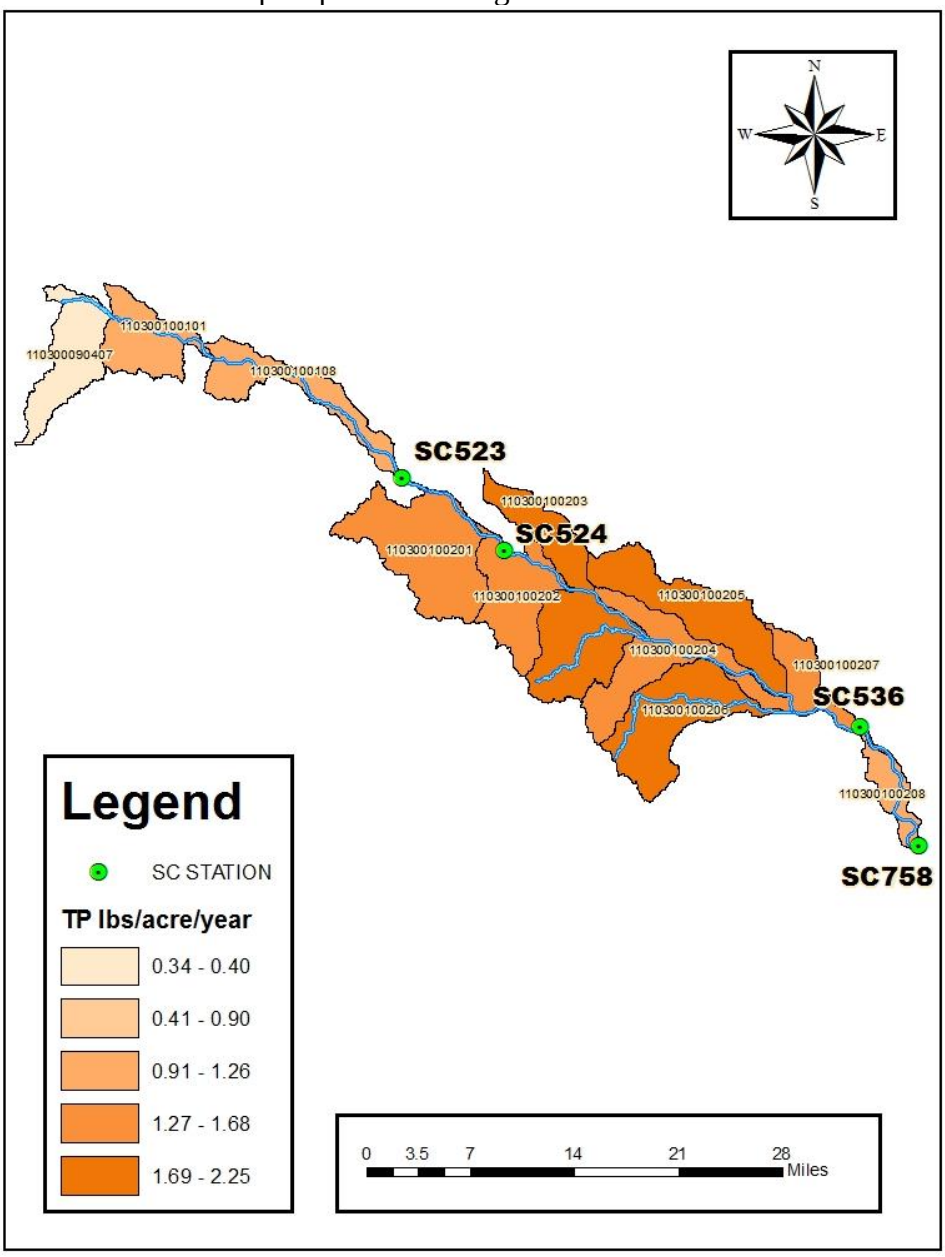
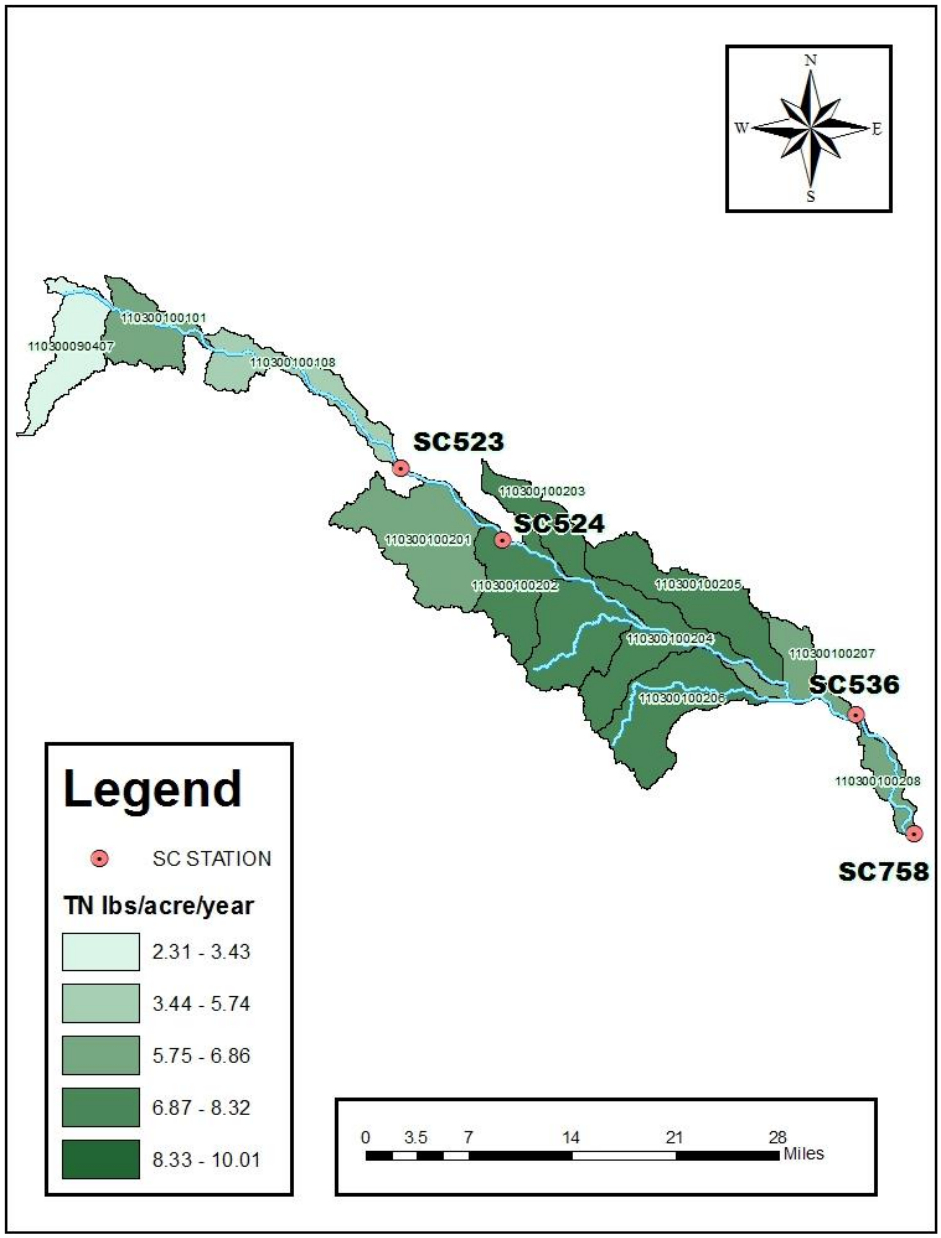


Figure 62. STEPL results for total nitrogen loading in the TMDL watershed.



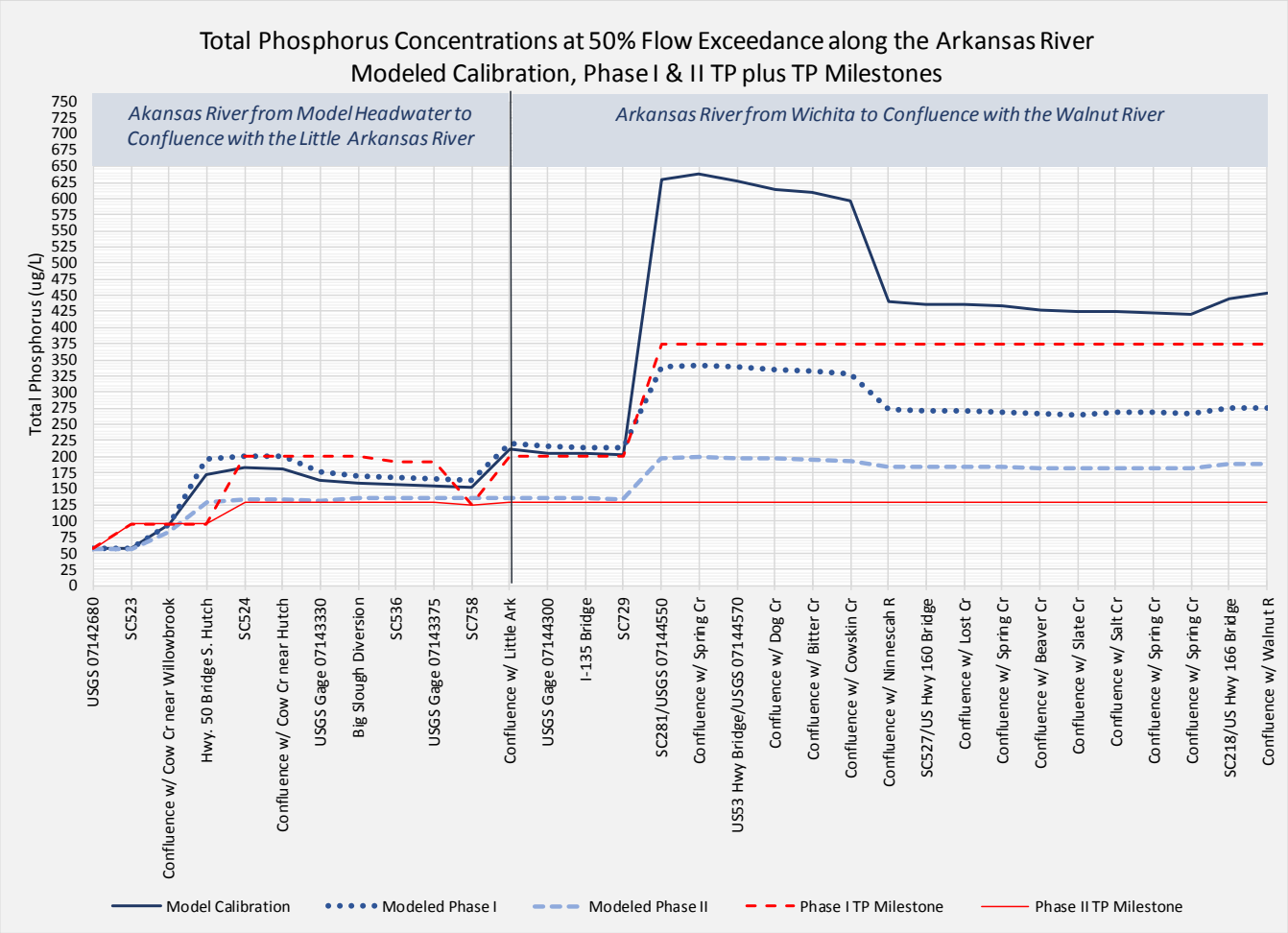
5. IMPLEMENTATION

Point Source Implementation Supporting Information: Qual2k is a steady-state model that was utilized to evaluate total phosphorus responses under the hydrologic flow conditions representing the median or 50th percent flow exceedance condition in the Lower Arkansas River from Nickerson to its confluence with the Walnut River below Arkansas City. The model run during the median flow represents the midpoint of flow conditions in the river where NPDES point source contributions were assessed for their load contributions into the Lower Arkansas River system. The primary purpose of the model was to assess the contribution from discharging point sources.

The modeling assessment concluded that, at median flow condition, the Phase I reductions in wasteload allocations will support the protective TMDL established at Hutchinson (SC523) and are likely to

achieve the ecoregional Phase I total phosphorus milestones of 200 μg/L at Yoder (SC524), 192 μg/L at Maize (SC536), 125 μg/L at Wichita (SC758), 374 μg/L in the Little Arkansas River above Wichita (SC729), 200 μg/L in the Arkansas River at Wichita (SC729), and 374 μg/L in the Arkansas River at Derby (SC281), Oxford (SC527) and Arkansas City (SC218). (**Figure 63**). For Phase II, municipal mechanical dischargers were set to an effluent concentration of 500 μg/L at design flow and modeled point-source tributaries with TP concentrations greater than 200 μg/L were reduced to that level in anticipation of future TP TMDL development for those streams. The modeled Phase II reductions demonstrate total phosphorus concentrations in the river should achieve the Phase II milestone of 130 μg/L from Yoder (SC524) to its confluence with the Little Arkansas River at Wichita (SC758). And, to remain consistent with the established methodology of applying lower quartile ecoregional total phosphorus values as management milestones in adaptive management total phosphorus TMDLs, a Phase II milestone of 130 μg/L has been established for the Little Arkansas River at Wichita (SC728) and in the Arkansas River from Wichita (SC729) to its confluence with the Walnut River below Arkansas City. However, during Phase II, the model shows total phosphorus concentrations in the river are strongly influenced by the loads being discharged by major municipal and industrial waste treatment plants along the river from Wichita (SC729) to Arkansas City (SC218). And although the modeled Phase II concentration at the river's confluence with Walnut River is about 190 μg/L, success in meeting the Phase II TP milestones will rely on future TMDL development and implementation as well as a concerted effort between the nonpoint sources, municipal wastewater facilities, and municipal stormwater (MS4) programs in the Arkansas River watersheds.

Figure 63. Total phosphorus concentrations long the Lower Arkansas River at 50% flow exceedance as modeled by Qual2k with approximate, non-equidistant river locations from Nickerson (Headwater) to the its confluence with the Walnut River below Arkansas City.



Desired Implementation Activities

1. Implement and maintain conservation farming, including conservation tilling, contour farming, and no-till farming to reduce runoff and cropland erosion.
2. Improve riparian conditions along stream systems by installing grass and/or forest buffer strips along the stream and drainage channels in the watershed.
3. Perform extensive soil testing to ensure excess phosphorus is not applied.
4. Ensure land applied manure is being properly managed and is not susceptible to runoff by implementing nutrient management plans.
5. Install pasture management practices, including proper stock density to reduce soil erosion and storm runoff.
6. Ensure proper on-site waste system operations in proximity to the main stream segments.
7. Ensure that labeled application rates of chemical fertilizers are being followed and implement runoff control measures.
8. Make operational changes in municipal wastewater treatment plants and implement alternative disposal such as irrigation and, if necessary, install enhanced nutrient reduction technology to reduce wasteloads.
9. Renew state and federal permits and inspect permitted facilities for permit compliance.

10. Facilitate urban and construction stormwater management in Reno and Sedgwick counties, including the cities of Hutchinson and Wichita to abate pollutant loads using best management practices to the maximum extent practicable.
11. The stakeholder leadership team for any active WRAPS group will coordinate best management practices to address:
    a. Livestock: vegetative filter strips, relocate feeding sites, relocate pasture feeding sites off-stream and alternate watering system.
    b. Cropland: waterways, terraces, conservation crop rotations and water retention structures.

NPDES and State Permits – KDHE

a. Monitor influent into and effluent from the discharging permitted wastewater treatment facilities, continue to encourage wastewater reuse and irrigation disposal and ensure compliance and proper operation to control phosphorus levels in wastewater discharges.
b. Establish applicable permit limits and conditions after 2022, with the initial implementation of goals and appropriate schedules of compliance for permits issued prior.
c. Establish TP concentration goal of 1.0 mg/L for all mechanical municipal wastewater treatment facilities in accordance with the WLA.
d. Manage the sum of WLA for the watershed to accommodate population growth as needed.
e. Inspect permitted livestock facilities to ensure compliance.
f. New livestock permitted facilities will be inspected for integrity of applied pollution prevention technologies.
g. New registered livestock facilities with less than 300 animal units will apply pollution prevention technologies.
h. Manure management plans will be implemented, to include proper land application rates and practices that will prevent runoff of applied manure.
i. Reduce runoff in MS4 permitted areas through stormwater management programs.
j. Establish nutrient reduction practices among urban homeowners to manage application on lawns and gardens, through respective stormwater management programs.

Nonpoint Source Pollution Technical Assistance – KDHE

a. Support Section 319 implementation projects for reduction of phosphorus runoff from agricultural activities as well as nutrient management.
b. Provide technical assistance on practices geared to the establishment of vegetative buffer strips.
c. Provide technical assistance on nutrient management for livestock facilities in the watershed and practices geared towards small livestock operations, which minimize impacts to stream resources.
d. Support the implementation efforts of any active WRAPS group in the watershed and incorporate long-term objectives of this TMDL into their 9-element watershed plan.

Water Resource Cost Share and Nonpoint Source Pollution Control Program – KDA-DOC

a. Apply conservation farming practices and/or erosion control structures, including no-till, terraces, and contours, sediment control basins, and constructed wetlands.
b. Provide sediment control practices to minimize erosion and sediment transport from cropland and grassland in the watershed.

c. Install livestock waste management systems for manure storage.
d. Implement manure management plans.

Riparian Protection Program – KDA-DOC

a. Establish or reestablish natural riparian systems, including vegetative filter strips and streambank vegetation.
b. Develop riparian restoration projects along targeted stream segments, especially those areas with baseflow.
c. Promote wetland construction to reduce runoff and assimilate sediment loadings.
d. Coordinate riparian management within the watershed and develop riparian restoration projects.

Buffer Initiative Program – KDA-DOC

a. Install grass buffer strips near streams.
b. Leverage Conservation Reserve Enhancement Program to hold riparian land out of production.

Extension Outreach and Technical Assistance – Kansas State University

a. Educate agricultural producers on sediment, nutrient, and pasture management.
b. Educate livestock producers on livestock waste management, land applied manure applications, and nutrient management planning.
c. Provide technical assistance on livestock waste management systems and nutrient management planning.
d. Provide technical assistance on buffer strip design and minimizing cropland runoff.
e. Encourage annual soil testing to determine capacity of field to hold phosphorus.
f. Educate residents, landowners, and watershed stakeholders about nonpoint source pollution.
g. Promote and utilize the WRAPS efforts for pollution prevention, runoff control and resource management.

Timeframe for Implementation: Reduction strategies for the wastewater treatment facilities should be evaluated by 2020 with subsequent planning, design, and construction of any expanded treatment initiated by the next permit starting in 2022. Urban stormwater and rural runoff management should be expanded in 2018 to ensure nutrients are addressed. Pollutant reduction practices should be installed within the priority subwatersheds before 2023 with follow-up implementation over 2023-2028. Phase I of this TMDL will occur from 2020 to 2040. If biology in the Arkansas River has not responded to Phase I reductions by 2040 then Phase II implementation will commence in 2041.

Targeted Participants: The primary participants for implementation will be municipal wastewater and stormwater programs, and agricultural and livestock producers operating immediately adjacent to the Arkansas River and its tributaries. Watershed coordinators and technical staff of any active WRAPS group, along with Conservation District personnel and county extension agents should assess possible sources adjacent to streams. Implementation activities to address nonpoint sources should focus on those areas with the greatest potential to impact nutrient concentrations adjacent to the river.

Targeted Activities to focus attention toward include:

1. Overused grazing land adjacent to the streams.
2. Sites where drainage runs through or adjacent to livestock areas.
3. Sites where livestock have full access to the stream as a primary water supply.

4. Poor riparian area and denuded riparian vegetation along the stream.
5. Unbufferred cropland adjacent to the stream.
6. Conservation compliance on highly erodible areas.
7. Total row crop acreage and gully locations.
8. High-density urban and residential development in proximity to streams and tributary areas.
9. Urban residents should be informed on fertilizer and waste management through their respective municipal Stormwater Management Programs to reduce urban runoff loads.

Milestone for 2024: By 2024, advancement of necessary and appropriate measures to decrease the effluent phosphorus content from the municipal wastewater facilities should be implemented. At that point in time, phosphorus data from the Arkansas River stream chemistry station SC523 should show no signs of an increase in median concentration and stream chemistry stations SC524, SC536, and SC758 should show indication of declining concentrations relative to the pre-2018 data, particularly during low flow conditions.

Delivery Agents: The primary delivery agents for program participation will be municipalities within the watershed, and KDHE.

Reasonable Assurances:
Authorities: The following authorities may be used to direct activities in the watershed to reduce pollution:

1. K.S.A. 65-164 and 165 empowers the Secretary of KDHE to regulate the discharge of sewage into the waters of the state.

2. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.

3. K.S.A. 2002 Supp. 82a-2001 identifies the classes of recreation use and defines impairment for streams.

4. K.A.R. 28-16-69 through 71 implements water quality protection by KDHE through the establishment and administration of critical water quality management areas on a watershed basis.

5. K.S.A. 2-1915 empowers the Kansas Department of Agriculture, Division of Conservation to develop programs to assist the protection, conservation and management of soil and water resources in the state, including riparian areas.

6. K.S.A. 75-5657 empowers the Kansas Department of Agriculture, Division of Conservation to provide financial assistance for local project work plans developed to control nonpoint source pollution.

7. K.S.A. 82a-901, et. seq. empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.

8. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the Kansas Water Plan, including selected Watershed Restoration and Protection Strategies.

9. The Kansas Water Plan and the Kansas Regional Action Plans provide the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority implementation.

Funding: The State Water Plan annually generates $12-13 million and is the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state through the Kansas Water Plan. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watershed and water resources of highest priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection. This watershed and its TMDL are located within a **High** Priority area and should receive support for pollution abatement practices that lower the loading of sediment and nutrients.

Effectiveness: Use of Biological Nutrient Removal technology has been well established to reduce nutrient levels, including phosphorus, in wastewater and Enhanced Nutrient Removal, including phosphorus recovery technologies, establishes phosphorus levels approaching pragmatic limits of technology. Additionally, nutrient control has been proven effective through conservation tillage, contour farming and use of grass waterways and buffer strips. In addition, the proper implementation of comprehensive livestock waste management plans has proven effective at reducing nutrient runoff associated with livestock facilities.

6. MONITORING

Future stream chemistry sampling will continue at SC523, SC524, SC536 and SC758 with sestonic chlorophyll *a* monitoring occurring at SC524 and SC758. Monitoring of tributary levels of TP for streams with existing KDHE monitoring stations will continue. Monitoring of TP should be a condition of the MS4 permits within the TMDL watershed.

Macroinvertebrate sampling will continue in the Arkansas River 3.0 miles north of Haven at SB283 and possibly at other accessible locations in the river. If the biological endpoints are achieved over 2024-2029, the conditions described by the narrative nutrient criteria will be viewed as attained and the impaired segments of Arkansas River as measured at SC524, SC536, and SC758 may be moved to Category 2 on the 2030-303(d) list.

Once the water quality standards are attained, the adjusted ambient phosphorus concentrations in the Arkansas River at Yoder (SC524), Maize (SC536) and Wichita (SC758) will be the basis for establishing numeric phosphorus criteria through the triennial water quality standards process to protect the restored biological and chemical integrity of the reaches of the Arkansas River.

7. FEEDBACK

Public Notice: An active Internet Web site is established at http://www.kdheks.gov/tmdl/planning_mgmt.htm to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Arkansas River Basin. This TMDL was posted to this site on April 5, 2018 for public review.

Public Hearing: A Public Hearing on this Lower Arkansas River Basin TMDL was held in Wichita, Kansas on April 27, 2018 to receive comments on this TMDL. No comments were received.

Milestone Evaluation: In 2024, evaluation will be made as to the degree of implementation that occurred within the TMDL watershed. Any active WRAPS group in the watershed will be consulted when making subsequent decisions regarding the non-point source implementation approach and follow up of additional implementation in the watershed.

Consideration for 303(d) Delisting: The Lower Arkansas River segments impaired for total phosphorus at Maize (SC536) will be evaluated for delisting under Section 303(d) based on the monitoring data over the period 2024-2029. Therefore, the decision for delisting will come about in the preparation of the 2030 303(d) list. Should modifications be made to the applicable water quality criteria during the ten-year implementation period, consideration for delisting, desired endpoints of this TMDL, and implementation activities may be adjusted accordingly.

Incorporation into the TMDL Vision Process, Water Quality Management Plan and the Kansas Water Planning Process: Under the current version of the Kansas TMDL Vision Process, the next anticipated revision would come in 2022, which will emphasize implementation of WRAPS activities and reduction of nutrients in wastewater developed by NPDES facilities. At that time, incorporation of this TMDL will be made into the WRAPS watershed plans. Recommendations of this TMDL will be considered in the Kansas Water Plan implementation decisions under the State Water Planning Process for Fiscal Years 2018-2026.

Developed September 13, 2018

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Appendix A. NPDES permitted facilities in the Arkansas River watershed from Hutchinson to Wichita with Phase I Wasteload Allocations. Data qualified with * is not available.

Permitee	NPDES Permit #	KS Permit #	Type	Permit Expires	SC Site	Design Flow (MGD)	Anticipated TP Concentration (mg/L)	TP WLA Daily Load (lbs/day)	TP WLA Annual Load (lbs/year)
Gravel & Concrete, Inc.	KSG110036	I-AR66-PR01	Ready Mix Plant	9/30/22	SC523	*	0	0	0
City of Nickerson	KS0098132	M-AR66-OO02	3 Cell Discharging Lagoon	3/31/23	SC523	0.1755	2	2.93	1,069.45
City of Alden	KS0051641	M-AR02-OO01	3 Cell Discharging Lagoon	9/30/22	SC523	0.024	2	0.40	146.00
Fun Valley Wastewater Treatment Lagoons	KS0080586	M-AR49-OO01	2 Cell Discharging Lagoon	3/31/22	SC523	0.0076	2	0.13	47.445
Whispering Pines Trailer Court	KSJ000192	C-AR82-NO02	Mobile Home Park	10/31/18	SC524	0	n/a	0	0
Morton International	KS0000345	I-AR82-PO01	Industrial - Salt	3/31/14	SC524	5.55	0.2	9.27	3,383.55
Former Farmland Industries – South Hutchinson	KS0098591	I-AR82-PO15	Groundwater Remediation	12/31/18	SC524	0.216	0.2	0.36	131.40

Permitee	NPDES Permit #	KS Permit #	Type	Permit Expires	SC Site	Design Flow (MGD)	Anticipated TP Concentration (mg/L)	TP WLA Daily Load (lbs/day)	TP WLA Annual Load (lbs/year)
Mid America Redi-Mix – Hutchinson	KSG110043	I-AR82-PR01	Ready Mix Plant	9/30/22	SC524	*	0	0	0
City of Hutchinson	KS0036188	M-AR49-IO01	Municipal Mechanical	12/31/18	SC524	8.3	1	69.34	25,309.10
City of South Hutchinson	KS0095711	M-AR82-OO02	Municipal Mechanical	11/30/22	SC524	2	1	16.71	6,099.15
Sonoco – Hutchinson Mill LLC	KS0033294	I-AR49-CO04	Industrial	11/30/18	SC536	0.055	0.2	0.09	32.85
Concrete Enterprises, Inc.	KSG110038	I-AR49-PR01	Ready Mix Plant	9/30/22	SC536	*	0	0	0
Reno Co. Sewer District #202	KS0091715	I-AR98-PO01	3 Cell Discharging Lagoon	12/31/18	SC536	0.02	2	0.33	120.45
City of Bentley	KSJ000471	M-AR11-NO01	Non-discharging Lagoon	10/31/18	SC536	0	n/a	0	0
City of Haven	KS0116815	M-AR41-OO01	4 Cell Discharging Lagoon	10/31/22	SC536	0.2488	2	4.16	1,518.40
Reno Co. Sewer District #201	KSJ000455	M-AR49-NO07	Non-discharging Lagoon	12/31/19	SC536	0	n/a	0	0
City of Mount Hope	KSJ000445	M-AR62-NO01	Non-discharging Lagoon	7/31/18	SC536	0	n/a	0	0
Marina Point Office Park	KS0090654	I-AR94-CO63	Non Contact Cooling Water	11/30/22	SC758	0.234	0.2	0.39	142.35
City of Wichita Water Plant	KS0099767	I-AR94-PO10	Drinking Water Plant Effluent	6/30/22	SC758	0.72	0.2	1.20	438.00